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SHEET-METAL PATTERN DRAFTING

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SHEET-METAL PATTERN DRAFTING

BY

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FRANK J. O'ROURKE AND JAMES A. MOYER

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PREFACE

Sheet-metal drafting has attained in recent years unusual importance, largely because of the changes that have come about in the construction materials used in making streamlined airplanes. These changes have been largely in the substitution of metal for wood in the fuselage.

All kinds of sheet-metal patterns are made by the same general methods current in industry, whether such patterns are needed for the manufacture of airplanes, steam boilers, tanks for water towers, automobile bodies, or air-conditioning duct work.

In planning this book, emphasis has been placed on the fundamentals that should be understood by every sheet-metal worker. A working knowledge of these fundamentals is necessary for every mechanic who desires to become a proficient sheet-metal layout man. It is obvious that it is not essential that every sheet-metal mechanic should be expert in drafting; but such proficiency will always be useful for determining the correct interpretation of difficult drawings and templates that the sheet-metal pattern draftsmen send to the shops for construction.

Many mechanics seem to be hesitant about trying to become expert in the development work accompanying sheet-metal pattern drafting. Pattern development, of course, requires some abstract thinking; but there is no reason why any intelligent mechanic cannot understand it with a little study of the fundamentals of the subject. When the fundamentals are thoroughly understood, practical experience will bring forth the desired results. Many otherwise expert sheet-metal workers are handicapped for advancement because they are unable to lay out difficult sheet-metal patterns, as required in the daily work of the shops. Although most sheet-metal mechanics acquire a great deal of skill by practical work, they are at a disadvantage if they lack the technical education necessary to enable them to become proficient in sheet-metal pattern drafting.

If a draftsman becomes skilled in the application of the methods that will be explained in this book, he will often be able to shorten

and simplify otherwise tedious designs in sheet-metal work; and in special cases he will be able to use methods of his own that will be suggested by study and experience.

Throughout this book, special attention is given to the fundamental principles that underly the current methods of sheet-metal pattern drafting. Practical shop problems in sheet-metal drafting of the kind that occur in everyday practice are discussed. In this way, the reader will be able to gain the practical viewpoint that comes to other mechanics only after many years of sheet-metal pattern work.

It should be noted that proficiency in advanced mechanical drawing is necessary.

For helpful suggestions in the preparation of this manuscript, the author is indebted to Ralph A. Greenleaf and Betsey McCausland, Instructors in Drawing in the Division of University Extension, Massachusetts Department of Education.

FRANK J. O'ROURKE.

Boston,
May, 1942.

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SHEET-METAL PATTERN DRAFTING

CHAPTER I

INTRODUCTION

The sheet-metal worker who wishes to be a specialist in his line today must have a more complete fundamental understanding of his subjects than ever before. While much practical experience may be gained through actual work in the shop, without further education he will lack theoretical knowledge that is necessary if he is to become a proficient sheet-metal draftsman and pattern cutter.

The object of this book is to familiarize the reader with the basic principles that must be applied in laying out patterns on sheet metal. For doing this effectively, a wide range of pattern demonstrations is given, and these must necessarily be studied carefully. The reader should never lack ready reference material for such work in pattern drafting if reasonable ingenuity is exercised in application of the examples given in the text. It will not be possible, of course, in such a small book to discuss all the types of work and the variations of those types that may be encountered. Those selected have been chosen because they are practical and illustrate the various methods. They are worked out accurately in every detail to cover the subject in a comprehensive way.

In sheet-metal drafting the accurate development of the size and shape of surfaces is very important. In general practice there are three commonly used methods of obtaining such developments. These are classified as follows:

1. Parallel-line method.
2. Radial-line method.
3. Triangulation method.

The first part of the book covers the so-called *parallel* forms, which relate to prisms and cylinders. The second part takes up the *radial-line* method, which is applied to all forms which are conical in shape. The last part of the book takes up the *triangulation* method, which applies to all kinds of irregular forms. This method can be used for the solution of problems to which the parallel-line and the radial-line methods are not applicable.

Each chapter includes typical cases showing the successive steps occurring in actual sheet-metal design and patternmaking. It is important in working out these different cases to follow accurately each step as indicated in the directions. The best way to learn any kind of pattern drafting is first to read the entire problem at hand, checking each step carefully with the dividers, and then to make a drawing on paper. The final step is the *checking* or *proving* of the drawing by the construction of a model made of thin cardboard. When making the model, bear in mind that there must be an allowance on some of the edges for seaming. In constructing actual patterns from sheet metal, various thicknesses or gages are used (page 182). However, for the development of the patterns in the first part of this book, usually the thickness of metal will be disregarded and no allowance will be made for forming.

Some familiarity with the methods of mechanical drawing is essential. In order to do good work in sheet-metal drafting, drawing instruments of good quality should be used. It is impossible to do good work in this subject when makeshift dividers or compasses are used. Inferior instruments by their inaccuracy will invariably cause faulty drawings and consequent discouragement.

EQUIPMENT REQUIRED

30- by 60-deg. triangle.	Good compass.
45-deg. triangle.	Good dividers.
Drawing board.	Triangular measuring scale.
T square.	Protractor.
Drawing pencils.	

Use of Supplementary Reference Sheets.—At the end of many of the chapters there will be found reference sheets to explain possible difficulties that may arise in following the successive steps for the type of work that is being explained. Since geo-

metrical constructions are the basis of all sheet-metal developments, many examples are presented in these reference sheets, so that they can be learned independently of any previous knowledge of geometry. For example, in this chapter there are construction problems to explain the various methods of dividing a given line, of making a so-called stretchout, and of using a cutting plane to lay out the *development* of a circle. There are also definitions[1] of words that must be understood when studying this subject, as well as supplementary reference sheets which are added to make the reading less difficult. They will encourage a systematic way of thinking and should help in working out appropriate solutions in typical developments and designs.

Developments.—A drawing or layout on a flat surface for determining the actual shapes of all the surfaces of an object is called a *development*[2] of those surfaces. It is obtained by *unfolding* or unrolling the entire area and placing it on a flat surface. This can be laid out in a single piece or by dividing the surface into sections, depending on the size and shape of the object.

A cube, a cylinder, a prism of almost any shape, and a cone are types of objects that may be readily developed. Sheet-metal objects that would be constructed on the same principles as the above geometrical forms are boxes, ducts, stovepipes, boilers, pans, tanks, funnels, covers for roof ventilators, hoods for ranges, and so on.

For practical purposes a sphere is not a developable surface.

Methods of Fastening Parts of Sheet-metal Sections.—The metals with which the sheet-metal man works range from 28 gage up to 14 gage (page 182). There are many methods of fastening or joining the edges of an object when sectioned. For round elbows the edges are either peened or riveted together. Curved elbows in rectangular pipe usually have the cheeks fastened to the back and the throat by means of a Pittsburgh lock. See Definitions, Chap. XVIII. On small work the curved elbow is usually joined together by means of a double-seamed lock. Ordinary smoke pipe is usually fastened by "locking the edges." This is called grooving. When heavy metals are used,

[1] In Chap. XVIII (p. 171) there is a convenient list of definitions.

[2] Simple theoretical explanations of intersections and developments are given in "Engineering Descriptive Geometry" by James A. Moyer, 4th ed., pp. 137–170 (John Wiley & Sons, Inc., New York).

the joints are either welded or riveted. Light metal may also be welded or riveted.

Measurement of Sheet-metal Forms.—When thin metal is used on round work, 3.1416 × D equals the mean circumference. If an inside diameter is required in round pipe of light or heavy metal, multiply the diameter plus one thickness of the metal being used by 3.1416. In duct work, specified dimensions between folding lines will make the opening in the duct the true size. If an outside dimension is required, two thicknesses of the metal have to be subtracted from specified measurements. For example, if a square tank were to be made of 16-gage iron, and it were to measure 4 ft. on the outside, the distance between the bending lines would measure 3 ft. 11⅞ in.

Paper Patterns.—Usually paper patterns are not required for square and round tanks, boxes, square and round pipe, or for many of the pipe fittings encountered in duct work. All of the above-mentioned objects can be laid out directly upon the metal. None of these forms requires an elevation or plan view, because the elements of the surface are parallel and have similar lengths. When the elements are of different lengths, however, such as the pattern for an elbow, it is best to lay out the work on paper, transferring the pattern shape onto the metal. If the pattern shape shows bend lines, these are transferred to the sheet iron by making light prick-punch marks. Prick-punch marks and scratch-awl lines should be avoided on tin, copper, and the newer metals—stainless steel and monel metal. Bend lines for these metals can be put in with a lead or soapstone pencil.

It is common practice in some shops to develop all the work directly on the metal. This method is a costly one, as the metal cannot always be cut to advantage without a great deal of waste. The best way to reduce cutting waste to a minimum is to first develop the form on paper, arranging it on the metal later. Paper patterns have an advantage over laying out on the metal. They may be tried by forming the paper to the desired shape of the finished object, as paper forms in exactly the same way as metal.

Explanation of Parallel-line Method.—The simplest method of developing geometric forms or surfaces to be made from sheet metal is the one which depends upon the use of parallel lines. The parallel-line method is applied to all forms that hold or keep

their shapes throughout the form. In other words, if an object has the same shape at both ends, it is a parallel form. The simple geometrical shapes encountered in the parallel-line method are composed of plane figures such as a square, rectangle, circle, oval, ellipse, and triangle. There are an unlimited number of parallel-line forms which have these shapes or combinations of the shapes. A perspective drawing is not required in the development of any form, but in some shops it may accompany a working sketch. Usually a perspective drawing is a good visual aid. Figure 1

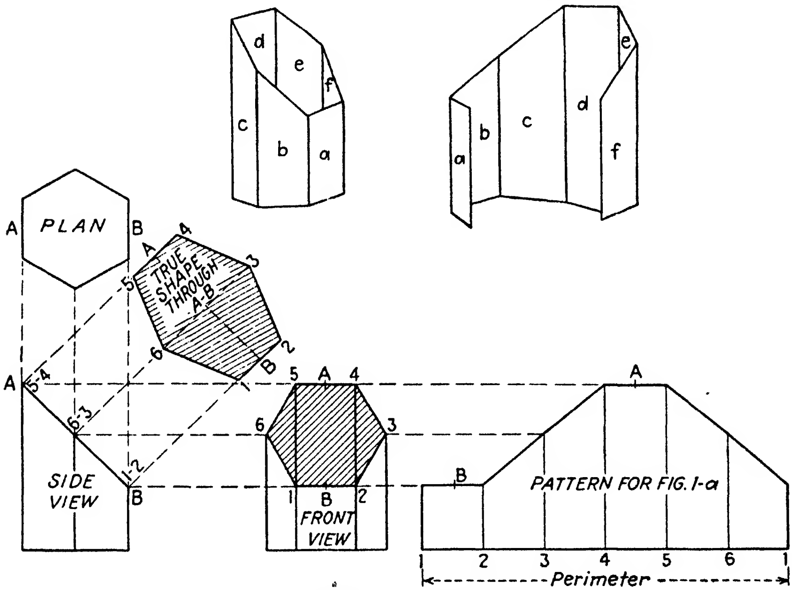


FIG. 1.—Hexagonal shaft "cut" by inclined plane.

shows a perspective drawing of a hexagonal shaft. The sketch is provided here to show the unrolling of the shaft and to give a mental picture of the pattern shape, which is drawn just below the perspective view. To the left of the pattern shape are orthographic views of the shaft. These views are drawn to shape and size as they are, not as they would be viewed in perspective. It is such views as these which are required for the development of any parallel-line form. The parallel-line method always produces a horizontal stretchout or perimeter. If the distance around a round object is spaced out onto a flat horizontal plane, it is called a *stretchout*. If the shape is

that of any polygon, the distance is called a *perimeter*. Figure 1 also shows the perimeter or distance around the plan placed on a horizontal plane as their true distances apart. The top part of the pattern shows a change in the direction on the lines.

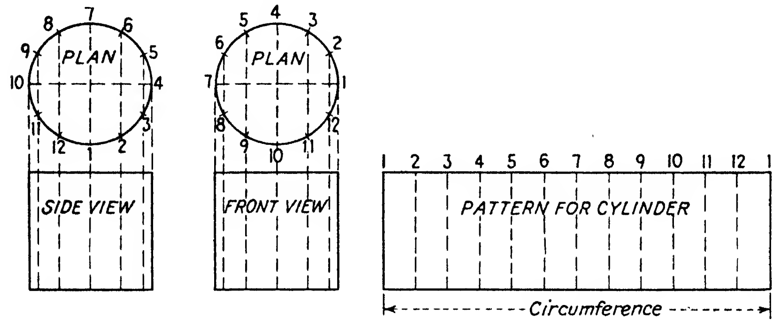


FIG. 2.—Elevations and stretchout of a cylinder.

This is because in the elevation the hexagonal shaft is cut at an oblique angle. The length of the irregular cut in the pattern shape is equal to the distance around the part marked true section. The true section is the true shape at the cutting plane

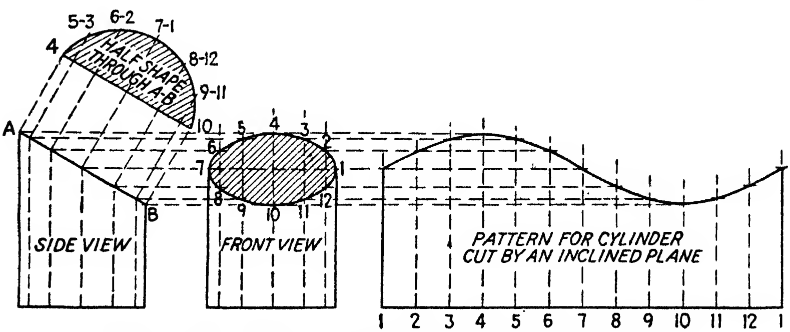


FIG. 3.—Two views of a cylinder "cut" by an inclined plane.

through *AB*. In Fig. 2[1] neither the front nor side views are required to produce the pattern shape of the cylinder, as the elements of the surface do not change. All lines are of the same height. The extra lines of the stretchout, therefore, are not required. If the spaces were taken from the plan and placed

[1] In the true development of a cylinder, the stretchout equals, of course, 3.1416 times the diameter. Note: see Supplementary Reference Sheet 1 (page 12).

in the stretchout, the length would only approximate the circumference. The general method for obtaining the stretchout for all round parallel-line forms is to multiply the diameter by 3.1416. The front view of a cylinder is the same as the side view. The numbers in the plan show which way it is being viewed. If a cylinder were to be cut at an oblique angle as shown in Fig. 3, a side view would be necessary to obtain the pattern shape, as the elements are of different heights. In the parallel-line method the true lengths of the parallel lines on the surface are projected at right angles from the various heights in the elevation to similarly numbered lines in the stretchout. The edge line of the girths will always equal those of the profile and sections.

Explanation of Orthographic Projection and the Use of Various Views in Sheet-metal Drafting. Elevations.—The view of an object, correct to dimensions, position, and shape, regarded directly or at right angles, is called an elevation of that object. There is no foreshortening in the elevation view.

Plan.—The plan is a top view of an object showing the shape and top and bottom measurements when the top and bottom planes in the elevation are parallel.

The plan view is drawn below the elevation in all drawings for sheet-metal drafting, for convenience in developing, as will be seen in succeeding chapters. A further discussion of the plan and elevation will be given later to show how the plan looks when the planes in the elevation are not parallel.

Sections.—A section is a view or a cut through any part of a solid. It is a correct representation of shape and size at any given point. Usually, in sheet-metal drafting, sections are developed on most vertical and inclined planes at their junction or miter line. It is often necessary to show a true shape at the junction, and a section must then be developed.

Figures 4 and 5 show the same object. In Fig. 4 the plan is simply a circle. In Fig. 5, however, the cylinder is in a horizontal position and is cut by a plane as shown. If a plan view were required as shown, the inclined plane in the elevation would be an ellipse in the plan. The ellipse is developed by drawing the full end section downward into the plan; and corresponding lines are drawn down from the inclined plane (1 to 7) in the elevation to intersect horizontal lines from 1 to 7 in the plan.

Ground Line.—*The dividing line between the elevation and the plan views (XY) is called the ground line.*

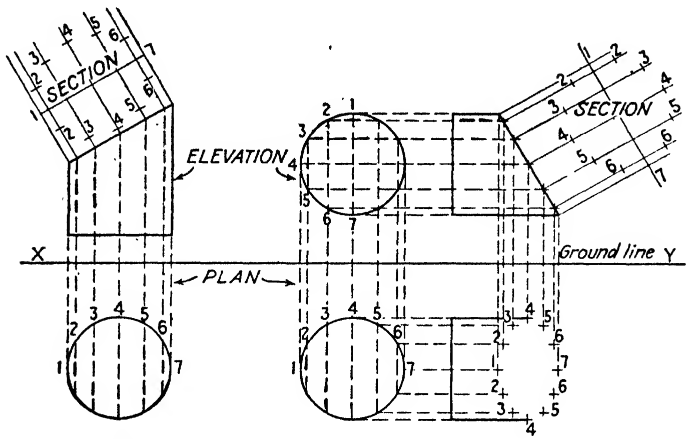


Fig. 4. Fig. 5.

Figs. 4 and 5.—Two views of the same object (cylinder "cut" by inclined plane), making elliptical section.

ILLUSTRATIVE EXAMPLES

According to instructions given here, the following examples will be worked out by making the necessary drawings:

1. *Roof flanges* (Figs. 6 and 7).
2. *Elbows* (Figs. 8 and 9).

Round Roof Flange for Intersecting Roof with 30-deg. Pitch.—Figure 6 is an elevation drawing of a flange on a roof. In this elevation drawing, the true shape of the opening in the roof is shown in the development. It will be seen from the half-profile drawing that the roof flange is circular. Only half of the profile drawing is needed for the development because obviously the two halves are symmetrical. The stretchout shows the true girth or circumference on a flat surface. To draw the roof flange and obtain the pattern shape of the cylinder cut by the plane *AC* adopt carefully the following successive steps:

1. As the roof line is to have a 30-deg. pitch, use the 30- by 60-deg. triangle, and draw the line marked *AC*.

2. Anywhere on the line *AC*, draw the elevation to show the diameter of the pipe size required. Make the distance 7^2-7 or 1^2-1 any reasonable length.

3. Draw the profile, which is a true half circle or true shape of half the cylindrical part of the roof flange.

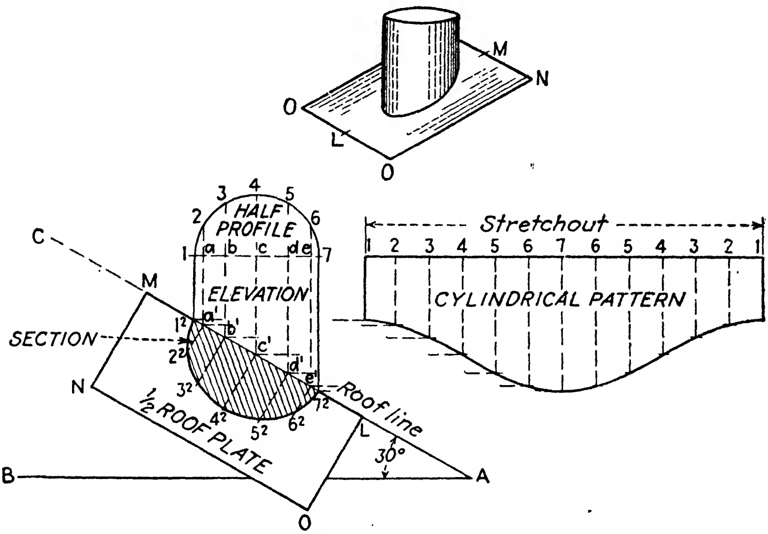


FIG. 6.—Round-pipe roof flange.

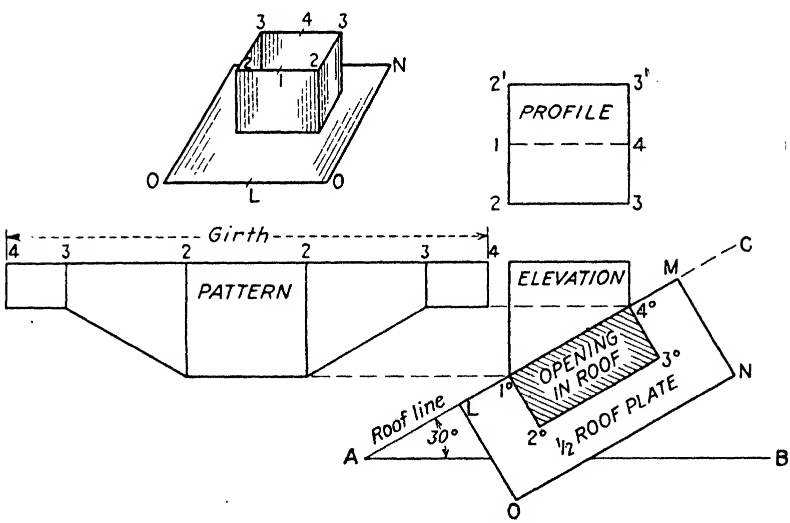


FIG. 7.—Square-pipe roof flange.

4. Divide the profile as instructed (see Supplementary Reference Sheet 1, Fig. 12).

5. Draw lines from points 1 to 7 in the profile, intersecting the roof line.

6. To show the true half shape of the opening in the roof at 1^2 to 7^2, take the spaces in the profile from *a* to 2, from *b* to 3, from *c* to 4, from *d* to 5, from *e* to 6. Then, lay off these spaces on

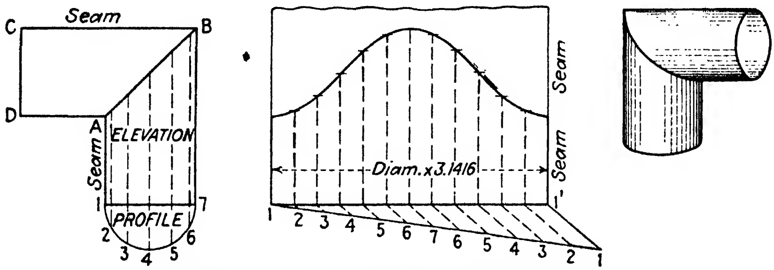


FIG. 8.—Two-piece 90-deg. round-pipe elbow.

lines drawn at right angles from the points marked *a′*, *b′*, *c′*, *d′*, and *e′*, thus locating 2^2, 3^2, 4^2, 5^2, and 6^2.

7. Draw a line through these points (2^2-3^2, etc.), and the result will be the true half section, which is the true half shape of the opening in the roof and in the roof plate.

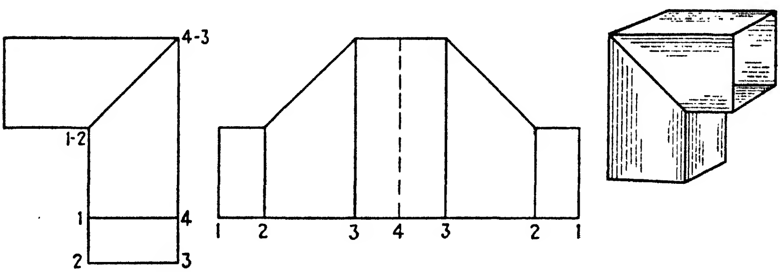


FIG. 9.—Two piece 90-deg. square-pipe elbow.

8. The half size of the roof plate is indicated by *MN* and *LO*. The lines are drawn at right angles to the roof line. The size of the roof plate is optional.

9. The next step is to obtain a true stretchout (circumference on the flat).

NOTE: See Supplementary Reference Sheet 1. The arc is longer than the chord. Compute the length of the stretchout required, and divide as instructed.

10. The stretchout shows equal spaces. From each point numbered 1 to 7, draw lines at right angles to the horizontal stretchout line.

11. Using the dividers, take off the various heights in the elevation. Place these heights on the corresponding numbered lines in the stretchout: $1\text{-}1^2$ on line 1, aa' on line 2, etc. On the other hand, lines may be projected from the roof line intersecting similar numbers in the pattern shape.

12. With care, using a French curve, draw a curved line through the points indicating the heights of the various stations on the stretchout. This completes the pattern shape for the cylindrical part (without laps).

Square-pipe Roof Flange.—The elevation in this case (Fig. 7) shows that the *square* is cut by an angle of 30 deg. (It is designed in the same way as the round roof flange.) A full profile is shown in this problem, and the girth shows that the seam is to be at point 4.

1. The girth is found by taking the distance around the profile, starting at 4 and going around the profile back to 4.

2. Drawing lines at right angles from points in the girth marked 4, 3, 2, 2, 3, 4, and intersecting them from similar points on the *miter line*[1] in the elevation completes the pattern shape.

3. The opening in the roof is found by taking the distances 1-2 and 4-3 in the profile, and placing these spaces in position on lines drawn at right angles from points 1° and 4° on the roof line.

4. The roof plate is the same as shown in Fig. 6. The only difference is in the shape of the opening.

Two-piece 90-deg. Round Elbows.—1. The miter line in this case is obtained from the oblique side of the 45-deg. triangle as shown through AB (Fig. 8), both arms as shown by CB, AD, $B7$, and $A1$ being similar.

2. Draw the semiprofile, and divide it into six equal parts. Project perpendicular lines from these points until they intersect the miter line AB as shown.

3. On the line, $1\text{-}1'$ is the true stretchout (diameter $\times$ 3.1416). Divide this line by using the geometrical method of dividing a given line (see Supplementary Reference Sheet 1).

[1] The *miter line* is the edge of a piece of material used to form a miter joint (page 37).

4. Erect vertical lines, and intersect them by horizontal lines drawn from similar intersections on the miter line *AB*.

5. A line traced through points obtained on the vertical lines in the stretchout will complete the pattern shape for one piece of the elbow.

Two-piece 90-deg. Rectangular Elbow.—1. The elevation of this elbow in Fig. 9 is designed exactly like Fig. 8. The half profile shows it to be a rectangular pipe. The stretchout is obtained by laying out the distance around the profile "on the flat" as shown, locating points 1,2,3,4,3,2, and 1.

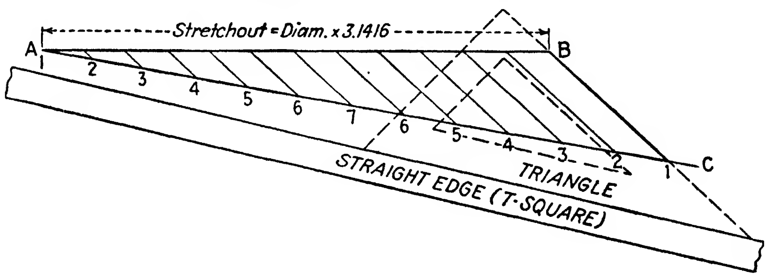


Fig. 10.—Method of dividing a given straight line.

2. Erect vertical lines from points in the stretchout. Horizontal lines drawn from similar numbers on the miter line will complete the pattern shape.

SUPPLEMENTARY REFERENCE SHEET 1

The geometrical method of dividing a line into equal parts is shown in Fig. 10. The explanation follows:

1. Draw a line *AB* of the desired length, as shown in the figure.
2. Draw the line *AC* at any angle.
3. Divide the line *AC* into 12 parts, setting the dividers at any reasonable space.

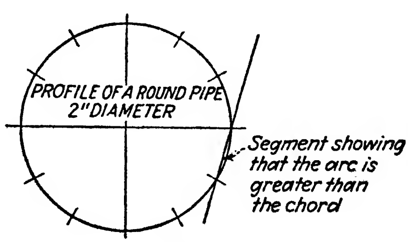


Fig. 11

4. Where the last division comes on the line *AC*, draw a line from this point to the point marked *B* in the stretchout.

5. Arrange the straightedge and triangle so that the triangle rests right on the line marked $1B$, and draw back the triangle along the working edge of the T square or straightedge. From each point encountered, draw a line to the horizontal stretchout line AB.

NOTE: If care is exercised, it will be found that, by making all the lines parallel to the line $1B$, the given length, or stretchout line, will now be divided into 12 equal parts.

It can be seen in Fig. 11 that the arc is greater than the chord. For this reason, the stretchout line is computed with the formula:

$$\text{diameter} \times 3.1416 = \text{circumference.}$$

A half-circular profile may be divided by using the 30- by 60-deg. triangle as shown in Fig. 12. A circular profile may also be divided by using the radius as follows: Describe an arc which will equal 60 deg., taking o as center and ox as a radius. With the 90-deg. point as a center and ox as a radius, the 30-deg. point is established. (The radius of any circle will divide a complete circle exactly into 12 equal parts.) See lower half of Fig. 12.

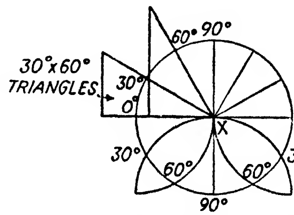


FIG. 12.—Method of dividing a circle.

As the arc of a circle is greater than the chord, the spaces should never be taken off the profile. The circumference should be computed on the flat; then the given length should be divided into 12 equal parts.

The stretchout, or circumference on the flat, sometimes referred to as the *girth* as in Fig. 13, is always computed for circular work (diameter $\times$ 3.1416).

Profile.—The profile always shows the shape of the object at its ends. Circular profiles are divided into an equal number of parts. For convenience, when the halves are symmetrical, only half of the profile is needed;

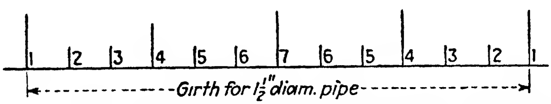


FIG. 13.—Alternative method of dividing a given straight line.

and this is usually divided into six equal parts for work in sheet-metal drafting.

Method of Dividing a Straight Line.—As the arc is greater than the chord, it is not advisable to use the spaces in the circular profile. It is better to compute the stretchout (diameter $\times$ 3.1416) for the length. A simple method for dividing a line into twelfths is to divide it into halves, then into quarters, and finally divide each quarter into three equal parts (see Fig. 13).

EXERCISES

1. Figure 6 shows a round roof flange. The cylindrical part intersects a roof at 30 deg. Make a similar roof flange 2 in. in diameter, intersecting a roof at 45 deg.

2. The drawings for a square-pipe roof flange are shown in Fig. 7. The size of the pipe is $1\frac{1}{4}$ in. square. Make a square-pipe roof flange 2 in. square, intersecting the same pitched roof.

3. Figure 8 shows a round elbow, 1 in. in diameter, made in two pieces forming a right angle. Make a round elbow with the same angle, of which the diameter will be 2 in., and develop the pattern shape. Use the given straight-line method (page 12) for dividing the *circumference* on the flat (stretchout).

CHAPTER II

ELBOWS

This chapter presents examples in *parallel-line* developments. Probably no problem so often confronts the sheet-metal worker as the construction of various types of elbows. Examples of round and rectangular-shaped elbows are selected for explanation here. If, however, other shapes are required, the general method of designing them and laying out the patterns remains the same.

An elbow may be made up of any number of pieces, and they usually join together to make an angle of 90 deg. Therefore, when mention is made of a two-piece, three-piece, or even five- or six-piece elbow, it is the right-angle kind that is meant, unless otherwise stated.

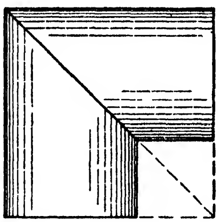


Fig. 14.

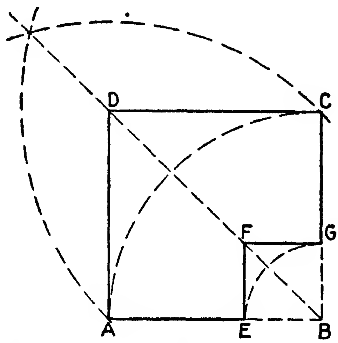


Fig. 15.

Figs. 14 and 15.—Designing a typical two-piece elbow.

It is important that the sheet-metal worker should understand, first of all, the method of obtaining the *miter lines* (page 11) or joints connecting the required number of pieces.

If the full elevation of an elbow is drawn, the miter lines may be found in any one of three ways:

1. By bisecting angles.
2. By using the triangle.
3. By using the protractor.

Figure 14 shows pictorially a typical two-piece elbow. The miter line may be formed by the method of bisecting angles in the following way, with reference to Fig. 15. The first step is to draw the right angle ABC and also the quadrant AC.

Bisect then the quadrant AC. This gives, of course, a 45-deg. miter line BD. Parallel to lines AB and BC (tangent to the quadrant at A and C), draw lines to intersect the diagonal at D. The diameter of the pipe is AE or CG. Draw the lines EF and FG parallel to DA and DC as shown, making a two-piece elbow with a 45-deg. miter line.

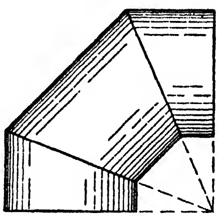


Fig. 16.

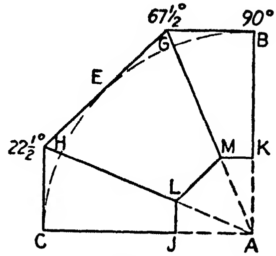


Fig. 17.

Figs. 16 and 17.—Designing a typical three-piece elbow.

Figure 16 shows similarly a three-piece elbow. It can be seen that the middle section is larger than the *end pieces*. The following simple rule for general layout work is applicable here as well as for elbows having any number of pieces. For each end piece, allow a count of one, and for each piece between the ends, allow a count of two. This is done because the middle piece is twice as large as the end pieces, as indicated by what is known as the *backset*. In this *three*-piece elbow, therefore, the count is as follows:

Top piece	1
Middle section	2
Bottom piece	1
Total	4

Divide the quadrant (90 deg.) by 4 (Fig. 17), which gives 22½ deg. Using a protractor, draw the lower miter line AH at 22½ deg. The middle section represents two parts (45 deg.); adding 45 deg. to 22½ deg. gives 67½ deg. Then draw the upper miter line at 67½ deg. at AG. Now draw a vertical line tangent at point C and a horizontal line tangent at point B.

Connect G and H with a line tangent to the quadrant at point E (at 45 deg.). Then lines CJ and BK indicate the diameter of the pipe. Draw the "under" lines of the elbow parallel to those of the back, as shown at L and M.

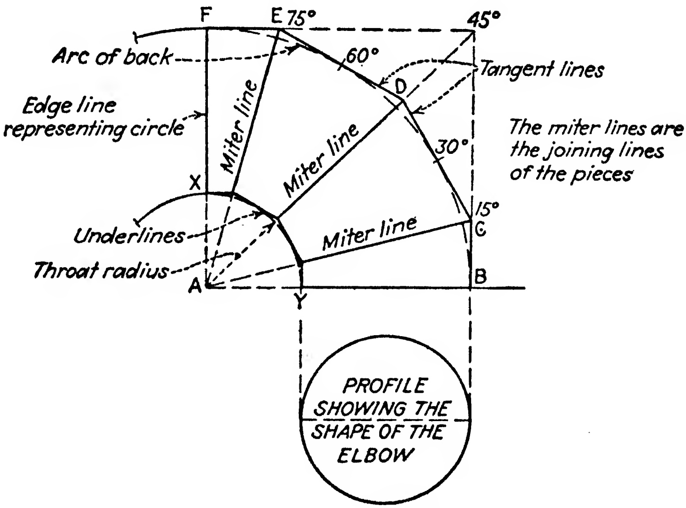


FIG. 18.—Elevation drawing of four-piece 90-deg. elbow.

Figure 18 shows a *four*-piece elbow. According to the count rule, as explained:

Top piece	1
Two middle sections (two each)	4
Bottom pieces	1
Total	6

The 90-deg. angle divided by 6 = 15°. The first miter line will be AC at 15 deg.; the second, AD at 45 deg.; and the third, AE at 75 deg. The layout of the elevation is completed by drawing lines tangent to the quadrant as shown. With this method an elbow having any desired number of sections can be laid out.

Figure 19 shows how the miter lines may be obtained for a three-pieced, 90-deg. elbow, by bisecting the angles.

The following steps are used in this method:

1. Draw any right angle, and mark its apex X.
2. Using X as a center, draw the radius of the throat, from 1 to L, of the elbow.

3. Then draw the diameter of the elbow (1-7); and using X as a center and $X7$ as a radius, draw the arc of the back of the elbow as shown by the lines from X to 9 and to 7 respectively.

4. Using point 7 as a center and the distance from 7 to 9 as a radius, draw an arc. Then with the same radius but with 9 as a center, draw an arc that will locate point D. Next, draw from D to X a line cutting the back of the arc at B. (Incidentally, this angle is 45 deg. and may be determined conveniently by using a 45-deg. triangle.)

5. Now using B as a center and $B9$ as a radius, draw another arc. Then using the same radius with 9 as a center, draw still another arc cutting the first arc at C. From point C draw a line to the apex X, determining the miter line ($8M$).

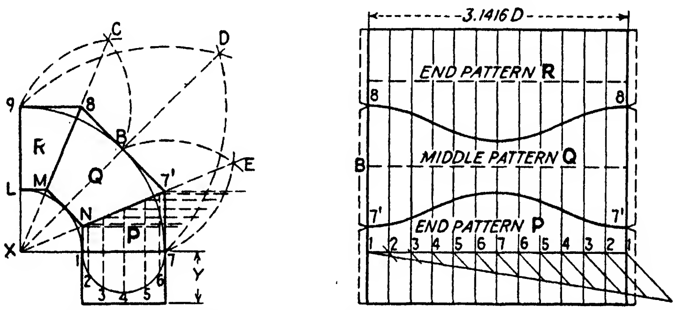


FIG. 19.—Design of three-piece 90-deg. elbow by method of bisecting angles.

6. By using the radiuses $7B$ and $B7$, respectively, point E is established exactly as was point C; and from E a line is drawn to the apex X, forming the miter line or juncture for the first piece P, marked $N7'$.

The next step is to complete the elevation, which will show the elbow as it will look when the patterns are put together.

7. Erect lines from point 7 and point 1 to intersect the miter line at $7'$ and at N.

8. Draw horizontal lines from point 9 and point L to intersect the miter line at points 8 and M.

9. If the drawing is correct, a line drawn from point $7'$ to point 8 will just touch the back of the arc at B.

10. The line NM should touch the inside of the arc in the throat.

11. The stretchout for the elbow is found by using the equation: diameter $\times$ 3.1416 = circumference, and dividing this

length into 12 equal parts. (Use the given straight-line method, page 12.) The end pattern P is developed like Fig. 8.

12. The end pieces P and R are the same with a straight pipe added. The distance Y in the elevation is added to the end pattern. Usually, the ends are too short, and this lengthening must be done to make a connection to a round pipe.

13. The middle section Q is twice the size of the end pattern P. Mark off the distance 7′-8 in the elevation on the vertical lines in the stretchout as shown, and cut out the end pattern P as would have to be done in practice. Turn over this pattern, holding and tracing it at points 8 in the stretchout. In this way patterns Q and R are obtained.

NOTE: Instead of cutting the end pattern out of the drawing, take a piece of paper, put it underneath the pattern shape P, and punch holes through it, with one of the pointed legs of a divider.

When the pattern is turned over to obtain the middle piece, the seams should be staggered, so that the metal can be cut without waste. Laps should be added to the pattern for joining at the ends.

No allowance is made for joining at the miters, as this alters the throat radius but does not affect the angle of the elbow.

It will be noticed that the pattern shape for the first piece P is exactly like the shape of the roof-flange pattern in Fig. 8.

All that is actually required for any elbow is the first or end pattern. All other pieces can be obtained from this pattern, regardless of the number of pieces the elbow may have.

When the full elevation is omitted, the throat of the elbow cannot be determined. The width of the middle pieces can then be of any suitable size, and changes in this size will not alter the angle of the elbow. Usually, on elbows from 6 to 10 in. in diameter, the width of the middle pieces in the throat is from 1 to 1½ in. On smaller elbows, the width is less.

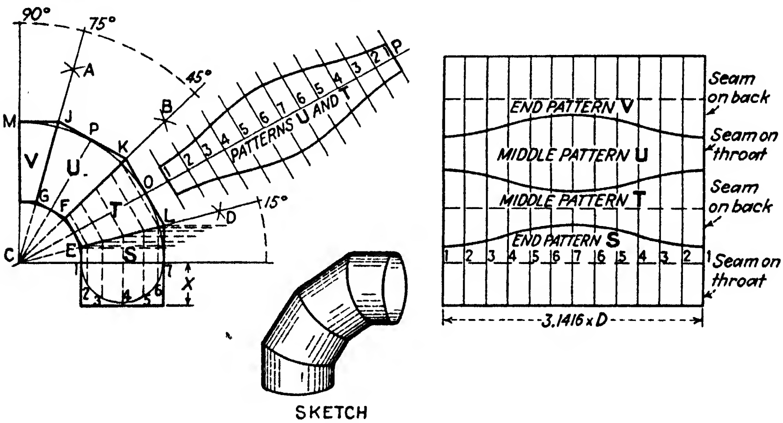
For blower-pipe elbows the full elevation should be drawn, as there must be an accurately definite throat measurement. These are called *long-radius elbows,* as they have a throat radius that is from 1½ to 2 times the diameters of the pipe.

Rule for Dividing Arc of Back of Elbow.—To obtain the rise of the miter line in any elbow when the full elevation is drawn, divide the arc of the back into divisions that are one less than the

number of pieces required. Then divide equally each such division.

Figure 20*b* shows a pictorial view of a four-piece elbow, and Fig. 20*a* shows the development for this elbow. The miter lines for the elbow can be located by using the above rule as follows:

1. To divide the arc of the back into a number of divisions that is one less than the number of pieces (triangles may be used for any four-pieced elbow): First make three divisions on the back arc of the elbow. Locate the point *O*, using the 30-deg. side of a 30- by 60-deg. triangle. Point *P* is located by using the 60-deg. side of the same triangle.



(*a*) (*b*) (*c*)

FIG. 20.—Typical design and pattern shapes for a four-piece 90-deg. elbow.

2. Bisect the angle *PM*, locating point *A*. Then draw a line from *A* to the apex *C* to provide a 75-deg. miter line.

3. Bisecting the angles *OP* and *7O* will likewise locate point *B* and point *D*, from which lines will be drawn to the center of the elbow at *C*. These will make 15- and 45-deg. miter lines.

4. To obtain the tangent lines in the elevation and the pattern shapes of the elbow, follow the same instructions given for Fig. 19.

In Figs. 19 and 20*c* it will be noticed that the patterns are obtained without waste of material. If all the middle patterns were like the pattern *U* and *T* Fig. 20*a*, there would be a considerable waste of material. This is done, however, when it is desired to keep the seams hidden.

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Protractor Method of Developing Elbows.—The computation for finding the rise in degrees of miter lines by the protractor method of developing elbows is the same as though the whole elevation were drawn.

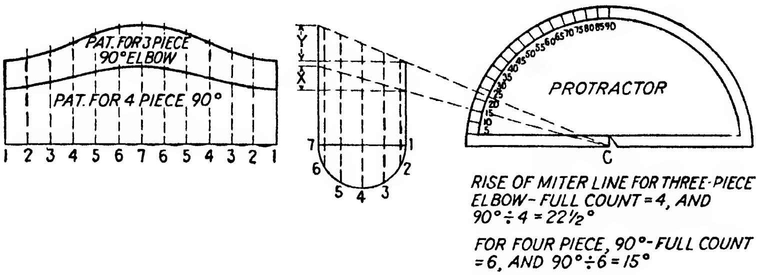


Fig. 21.—Protractor method of developing elbows.

With the protractor method the whole elevation need not be shown. Figure 21 shows the development of two different patterns. One elbow is to be made of three pieces, and the rise of miter is 22½ deg., as indicated on the protractor. The other miter line is at 15 deg. and will make a 90-deg. elbow with four pieces. The rise of the backsets is indicated at X and Y. The four-pieced elbow has a rise marked X, and the three-pieced elbow is marked Y.

Figure 22 shows the bisecting method for the above-described three-piece elbow when the elevation is desired.

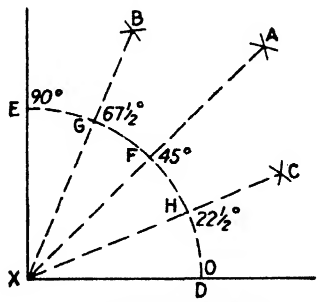
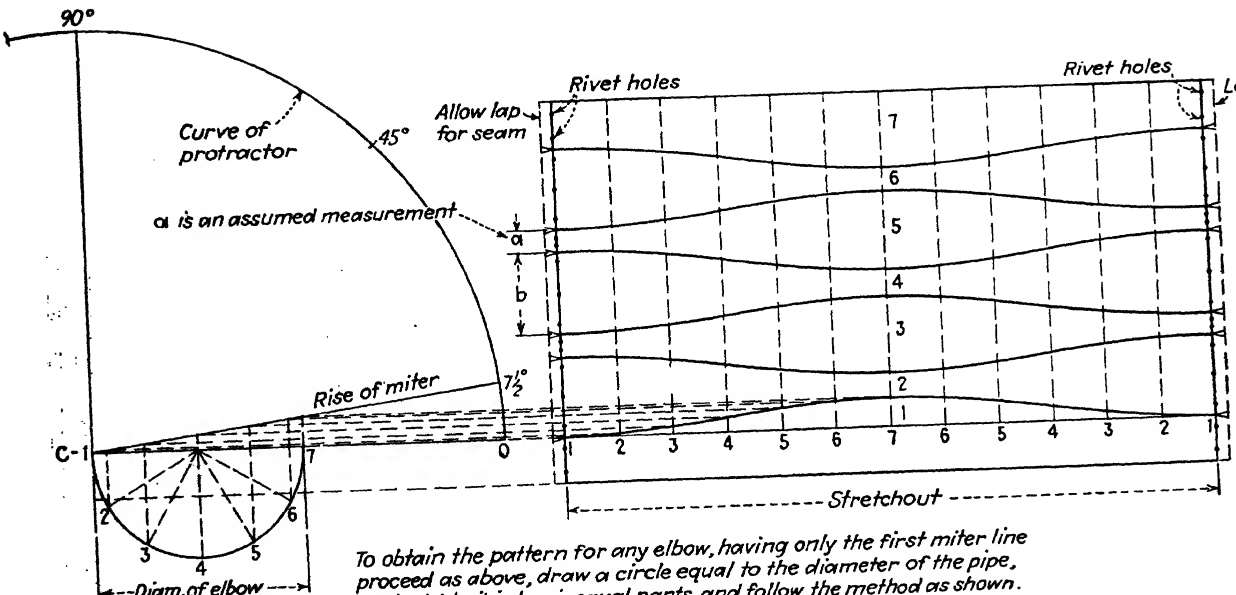


Fig. 22.—Example of bisecting angles.

How to Use the Protractor.—The method of using a protractor is as follows:

1. Draw any right angle. In Figs. 21 and 23 the middle of the angle is marked C.
2. Place the protractor so that its mid-point is exactly on C and the vertical and horizontal parts of the right angle are directly under 90 deg. and O.
3. Mark off the various degrees computed, and draw these points back to the middle of the right angle C.



To obtain the pattern for any elbow, having only the first miter line proceed as above, draw a circle equal to the diameter of the pipe, and divide it into six equal parts, and follow the method as shown.

For a seven piece 90° elbow the count is 12 and $90 \div 12 = 7\frac{1}{2}°$ which is the rise of the first miter line

FIG. 23.—Developing elbows by protractor method.

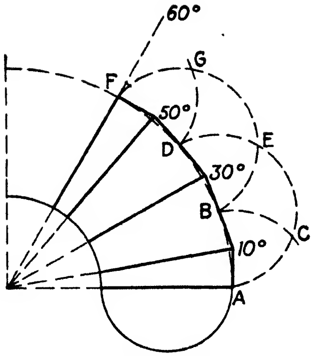


Fig. 24.

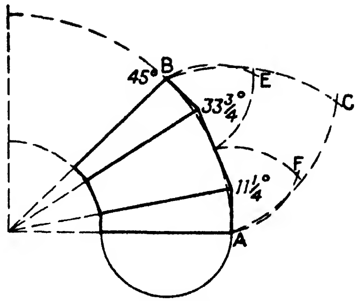


Fig. 25.

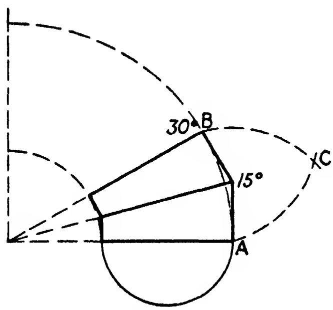


Fig. 26.

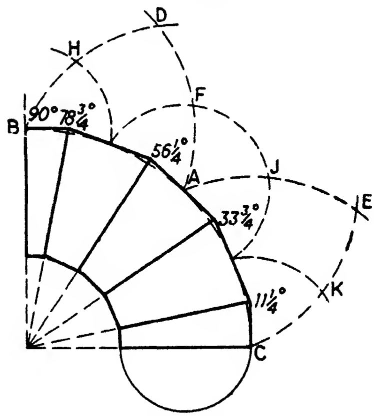


Fig. 27.

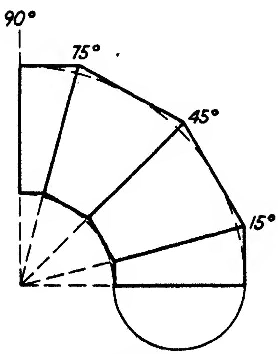


Fig. 28.

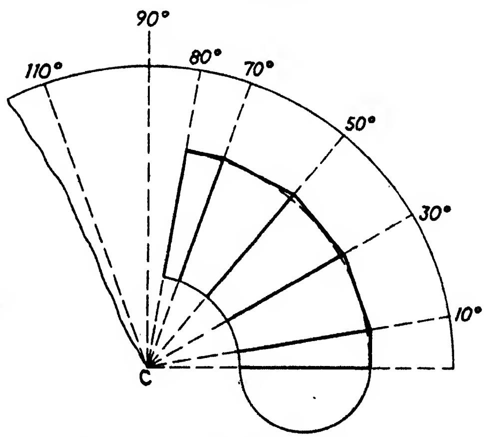


Fig. 29.

Figs. 24 to 29.—How to design elevations of elbows by using various methods of

Figures 24–29 show both ways of finding the miter lines for elbows at any angle and having any number of pieces. They are (1) by bisecting angles, (2) by using the protractor.

Figure 29 shows how the protractor is used for finding the rise in degrees of miter lines in an elbow of 80 deg. having five pieces.

Example. If an 80-deg. elbow has three middle pieces and two ends, the full count is:

Top piece	1
3 middle sections (3 × 2)	6
Bottom piece	1
Total	8

Rise in degrees of miter lines is 80 ÷ 8 = 10 deg.

INSTRUCTIONS FOR THE DEVELOPMENT OF OFFSET ELBOWS IN THREE PIECES—FIGS. 30 AND 31

In the elbow shown in Fig. 30, the offset is $1\frac{1}{2}$ in. between the center lines of the end pieces Q and S. As the vertical

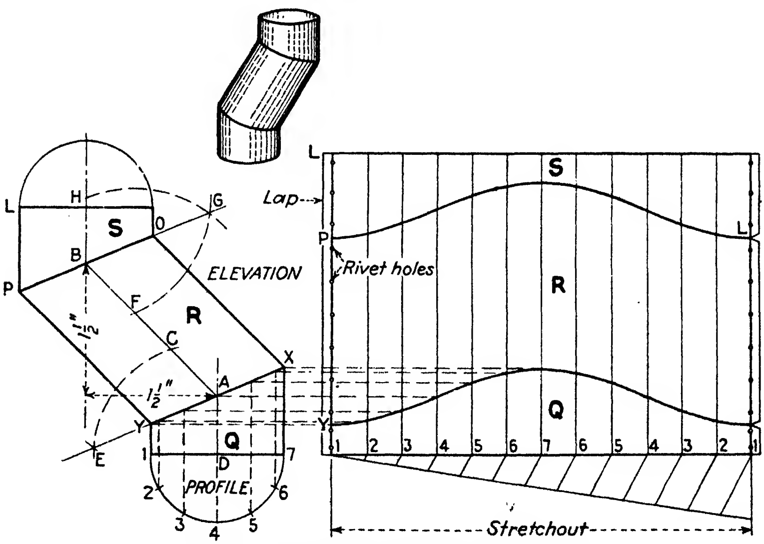


FIG. 30.—Three-piece offset in round pipe.

distance between points A and B is also $1\frac{1}{2}$ in., the center line of the middle section is drawn at 45 deg.

1. To obtain the miter lines, mark the middle of the angles A and B, and from these centers draw any circle cutting the legs of the angle at DC and FH.

2. Using H as a center and HF as a radius, draw an arc. Using this same radius with F as a center and FH as a radius, draw an arc establishing the point G. From point G draw a line through the middle of the angle B, and the result will be the miter line.

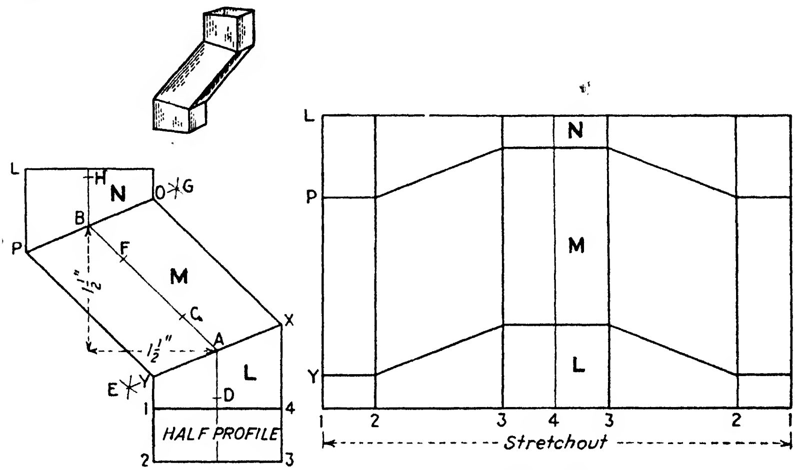


FIG. 31.—Three-piece offset in square pipe.

3. The miter line through A is found in the same manner.

4. Draw the semiprofile, and erect lines from 7 to 1, intersecting the miter line XY.

5. To complete the elevation, draw lines parallel to the center line BA, from X and Y, establishing points O and P.

6. From points O and P erect perpendicular lines to complete the end section S, which is the same as the end section Q.

7. The end pattern for the offset is found in the usual way. (As for P, Fig. 19.) The middle section R is found by taking the distance in the elevation XO or YP and placing this height on each vertical line erected in the stretchout.

NOTE: These lines may be omitted. The end pattern can be moved up to P and L and traced.

8. The end sections S and Q are the same. The end piece Q will have a seam in the throat, and the end piece S will have a seam on the back.

RECTANGULAR-PIPE OFFSET

This case needs no explanation. It is designed exactly like Fig. 30. The only difference is that the profile is a rectangle. (Refer to Fig. 7 for the method of obtaining the stretchout of a rectangular pipe.) The profile of the rectangular offset may be made about 1½ by 1¼ in. Only half of the profile is required (as marked 1, 2, 3, and 4).

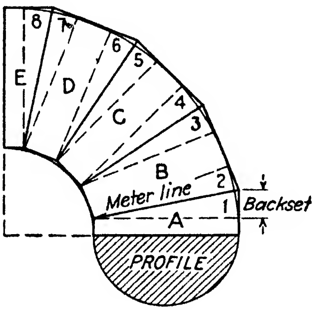


Fig. 32.—Elevation of an elbow showing backsets.

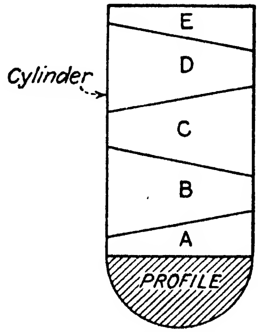


Fig. 33.—Swiveling the elbow in Fig. 32 at the miters to form a straight pipe.

SUPPLEMENTARY REFERENCE SHEET 2

An elbow is a cylinder cut by one or more planes. The cutting planes are called miter lines, which are, therefore, the junctions or joining lines of any two sections of the elbow.

If, in Fig. 32, the joints were swiveled, sections *A*, *B*, *C*, and *D* could be turned to form a straight piece of round pipe as in Fig. 33.

Elbows are made in many sizes and at various angles. If the elbow is to have a definite throat measurement, the full elevation should be drawn. If only the angle of the elbow is desired, the elbow should be developed by the protractor method; only part of the elevation is then required (see Figs. 21 and 23).

Each of the above methods is equally accurate for finding the miter line of the end section. The rise of the miter line of the end section is all that is required for any elbow, regardless of the number of pieces that the elbow may have, or whatever the angle of the elbow is to be.

Figures 19 and 20 show the elevation and pattern shapes of a three- and four-piece 90-deg. elbow. The miter lines in Fig. 19 are found by bisecting angles. In both elbows all that is necessary are the end sections *P* and *S*, as the middle pieces have two backsets and each end has only one. Therefore, the middle sections are twice the size of the ends. In Fig. 32 the backsets are drawn and numbered. It will be noticed that between each backset

there is a straight part. If this straight part is altered in any way it does not change the angle of the elbow. This is geometrical proof that the protractor can be used to advantage by assuming a throat measurement for the middle pieces.

As each middle piece is twice the size of an end, the middle pieces count two, and each end piece counts one.

In Fig. 32, there is a full count of 8, the angle of the elbow is 90 deg. Therefore, 90 ÷ 8 = 11¼ deg., which is the rise of the first miter for any elbow having five pieces at an angle of 90 deg.

Many times an elbow having an acute angle will be made from an angle taken with a bevel. The legs of the angle should be of the same length as indicated, *dm* and *dl* in Fig. 34.

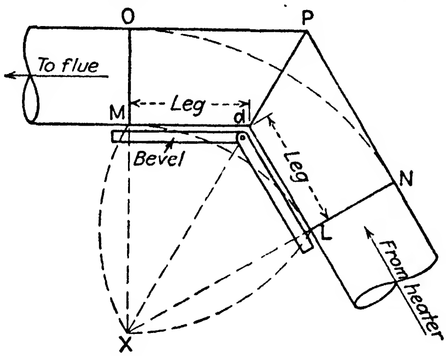


Fig. 34.—Use of a bevel for laying out elbows at any angle other than 90 deg.

The bevel should be bisected to locate the apex *x*, the point from which the arc of the throat and back is drawn. By drawing the profile and following the procedure as shown in Figs. 24 and 25, the acute angle may be made in any number of pieces. If the angle of the elbow is known, then the use of the bevel is not necessary. The protractor may be used for finding the rise of the end piece.

EXERCISES

There are five elbows, marked Figs. 24, 25, 26, 27, and 28.

Develop the pattern shapes for the elbows by using the following methods for locating the miter lines:

Figures 24, 25, and 26. Bisect the angles. (Use the 45-deg. and 30- by 60-deg. triangles to locate some of the miters.)

Figure 27. Develop the miters by using the protractor.

Figure 28. Develop the patterns, using only the end piece (Protractor method).

Note: In each case make the diameter 2 in. and the throat radius 1½ in.

Figure 30 shows a three-pieced offset in round pipe. The diameter is 1¾ in., and the amount of offset between the center lines is 1½ in.

Make a similar offset that will have a 2-in. diameter and a 2½-in. offset between the center lines.

CHAPTER III

TEE PIPE JOINTS

This chapter requires the application of the principles studied in Chaps. I and II. No supplementary reference sheets are necessary.

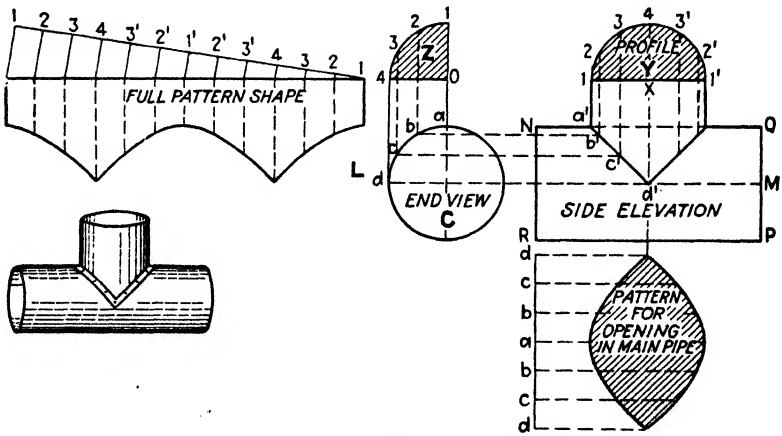


Fig. 35.—Ninety-degree tee joint between pipes of the same diameter.

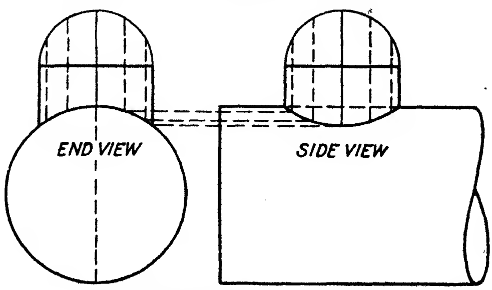


Fig. 36.—Ninety-degree tee joint of different diameters.

In this chapter the profiles and stretchouts of the following cases are explained:

1. 90-deg. tee joint of the same diameters—Fig. 35.
2. 90-deg. tee joint of the different diameters—Fig. 36.

3. 45-deg. tee joint of the same diameters—Fig. 37.
4. 45-deg. tee joint of the different diameters—Fig. 38.

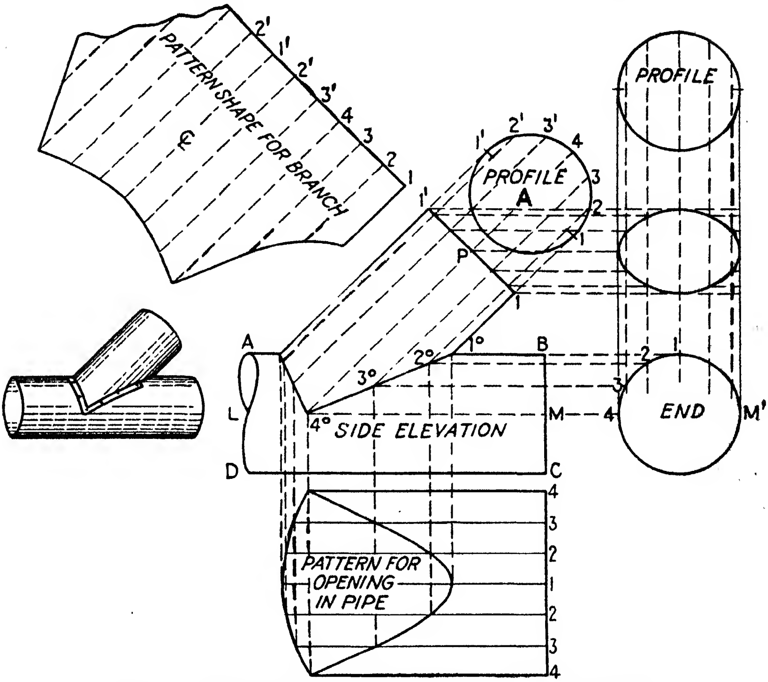


Fig. 37.—Pitched tee between pipes of the same diameter.

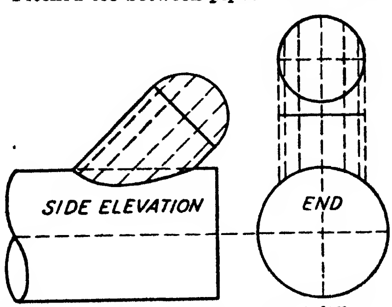


Fig. 38.—Pitched tee joint between pipes of different diameters.

5. 45-deg. tee joint of the different diameters placed off centers—Fig. 39.

Figure 35 shows a 90-deg. tee joint between two pipes of the same diameter.

1. In constructing the elevation of these pipes, first draw the horizontal center line marked L and M at its ends. On this line, at a suitable distance, draw the half profile of the end view C, and also draw the side views of the pipe marked NR and QP so that the distance between the lines NQ and RP will be suitable.

2. In the end view C, draw lines at right angles to the center line LM, from d to 4 and from a to O, making this distance cor-

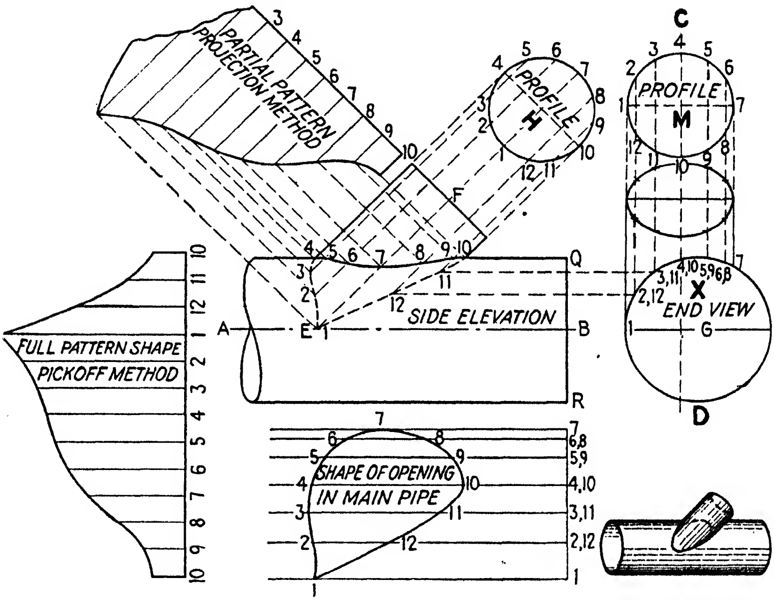


FIG. 39.—Pitched tee joint of different diameters placed off center.

respond to the desired height of the cylindrical collar. Then connect points 4 and O. Next, with O as a center and $O4$ as a radius, draw the quarter profile, Z, and divide its arc into three equal parts, as marked 1, 2, 3, and 4.

3. Draw lines from points 1, 2, 3, and 4 on the collar profile to the curve of the horizontal pipe, locating points a, b, c, and d.

4. Draw a convenient center line at right angles to LM in the side elevation as marked $d'x$, making $d'x$ the same height as $d4$ in the end view.

5. With X as a center, draw the profile of which the diameter is indicated by points 1 and 1'.

6. Divide the circumference of the profile into six equal parts, as numbered from 1 to 1′, and extend these points downward to intersect similarly numbered positions drawn horizontally from the end profile C, which completes the junction line $a'd'$.

7. The stretchout and pattern shape are constructed in the same way that the end pattern is made for an elbow, except that the numbering of the various points along the stretchout is different. Thus, in elbows, the halves of the pattern shape are the same and are numbered from 1 to 7. In *straight*[1] *tees*, the quarters are the same and should be numbered from 1 to 1′ as shown.

8. To determine the shape of the opening in the pipe, a line is drawn at any convenient point at right angles to the line RP in the side elevation. Along this line place the girth of the end profile marked a, b, c, and d; and draw lines from these points, horizontally and at right angles, intersecting similarly numbered points drawn downward at right angles from the line NQ in the side elevation. A line drawn through these established points completes the shape of the opening.

Figure 36 shows a 90-deg. tee joint between pipes of *unequal* diameters.

The same procedure is followed for obtaining the pattern shape as in Fig. 35. The only difference is that the intersecting pipe collar is smaller. This construction should require no further explanation.

Figure 37 shows two cylindrical pipes of the same diameter, one intersecting the other at an *oblique angle*.

1. In this case no end view is necessary. For this type of tee, however, an end profile of the pipes may be drawn to help in the solution. Draw the end profile, and at a suitable distance, draw the side view marked with the lines AB and DC, making the edges AB and DC any reasonable lengths.

2. Draw the horizontal center line LM, and from any convenient distance between L and M draw the angle of the tee. In this case, a 45-deg. angle will suffice for the center line as marked at points 4° and P. The length of the tee is usually made short, and after the pattern is obtained the straight part may be lengthened or shortened to meet requirements.

3. At right angles to the line $4°P$ draw the line 1′-1. Then with P as a center and $P1$ as a radius, draw anywhere on the

[1] A straight tee is one which intersects in a T shape another pipe at 90 deg.

extended line 4°P the half profile A, and divide its semi-circumference into six equal parts, numbering each division as indicated from 1′ to 1.

4. From points 1′ to 1 in the profile A extend lines running parallel to 4°P or at 45 deg., until these lines intersect similarly numbered horizontal lines drawn from points in the end elevation.

5. The pattern shape of the tee and the shape of the opening in the horizontal or main pipe are developed exactly like those in Figs. 35 and 36. Note that Fig. 38 is developed exactly like Fig. 37.

Figure 39 shows a type of tee joint for which it is necessary to develop two cutting planes, as the intersecting pipe is at an oblique angle, has a different diameter, and is placed off the center.

1. The methods given for tees can be applied to pipes of any size. First draw two center lines AB and EF meeting at the required angle at the point E in the side elevation.

2. From a center conveniently located upon the line AB, extended as at G, draw a circle equal to the diameter of the large pipe.

3. Draw the center line in the end view CD to obtain the amount of offset desired; on this line place at a reasonable distance the profile M.

4. At a reasonable distance on the center line EF in the side elevation draw the profile H.

5. Divide the circumferences of the profiles M and H into 12 equal parts, and number them as indicated.

6. From points in the profile H extend lines downward, parallel to the center line FE (of the smaller pipe). Also from points in the profile M extend lines parallel to the center line CD, intersecting the curve of the pipe in the profile X, as indicated by numbers 1 to 12.

7. From points numbered 1, 2, and 12; 3 and 11; 4 and 10; 5 and 9; 6 and 8; and 7, horizontal lines are then constructed to *intersect* similarly numbered points drawn obliquely from the profile H. If now a line is drawn through these points of intersection, it will be seen that the two *cutting planes* have been developed.

8. The procedure for the pattern shape is exactly the same as for elbow ends. However, as the halves are not the same,

the whole profile must be drawn and then numbered all around from 1 to 12, which is exactly the way the stretchout is numbered. By intersecting lines with corresponding numbers, drawn at right angles from the *oblique* lines in the side elevation,

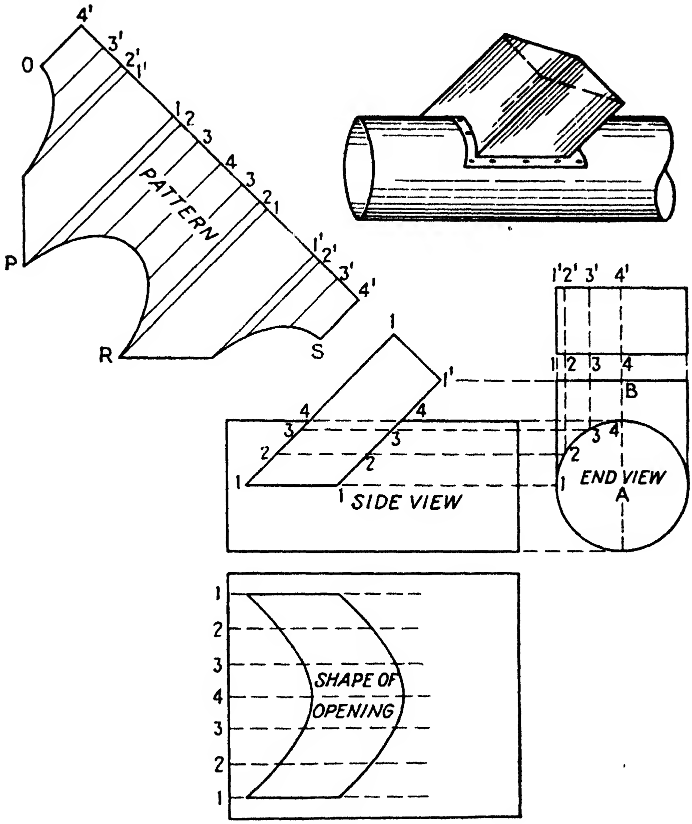


Fig. 40.—Pitched tee joint between square and round pipe.

to lines drawn at right angles from points marked 1 to 12 along the stretchout, the pattern shape will be obtained.

Note: The *pickoff method* (Fig. 39*a*) of transferring lengths may be used, as shown for the pattern shape. Instead of projecting the heights of the elements as described, they may be picked off the side view and placed in the pattern shape, by using the dividers.

9. The girth for the opening is found by taking the spaces around the curve of the pipe in the end view X and placing them

in a vertical position, or on a line drawn at right angles from the horizontal center line AB, as marked on the extended line QR.

10. From the points of the girth on the extended line QR, horizontal lines are drawn, intersecting similarly numbered points projected from the two cutting planes in the side elevation.

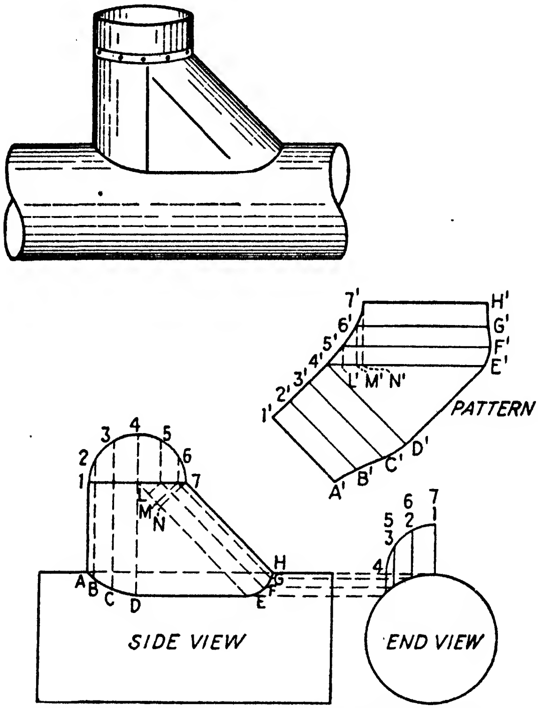


Fig. 41.—Ninety-degree tee joint, one side of which is drawn obliquely. This fitting is sometimes called *shoe tee.*

A line drawn through these points of intersection completes the pattern shape of the opening in the main pipe.

In the additional views given in Figs. 40 and 41, the same principles apply that were explained in the preceding examples.

EXERCISES

1. The drawing for a 90-deg. tee joint between pipes of a similar diameter is shown in Fig. 35. Make a similar drawing of which the diameters will be 2 in.

2. Develop a similar pattern shape for Fig. 38. Make the horizontal (main pipe) 2 in. in diameter; this is to be intersected by a smaller pipe 1¼ in. at an angle of 30 deg.

3. It is shown in Fig. 39 that the intersecting pipe is off the center. Make a similar drawing using the following dimensions:

Large diameter	=	2 in.
Diameter of small pipe	=	1½ in.
Angle of tee	=	30 deg.

4. Another type of tee is shown in Fig. 41. Make a drawing for this type of tee to the following dimensions, assuming that the intersecting pipe is to have angles of 90 and 45 deg.:

Large diameter	=	3 in.
Small diameter	=	2¼ in.

CHAPTER IV

CORNICES

Sheet-metal cornice work has made rapid progress in the building trade. From a simple tin-shop business, it is fast becoming a substantial industry. In the past, sheet-metal cornices were usually duplications of designs previously constructed of stone or wood. At the present time, however, there

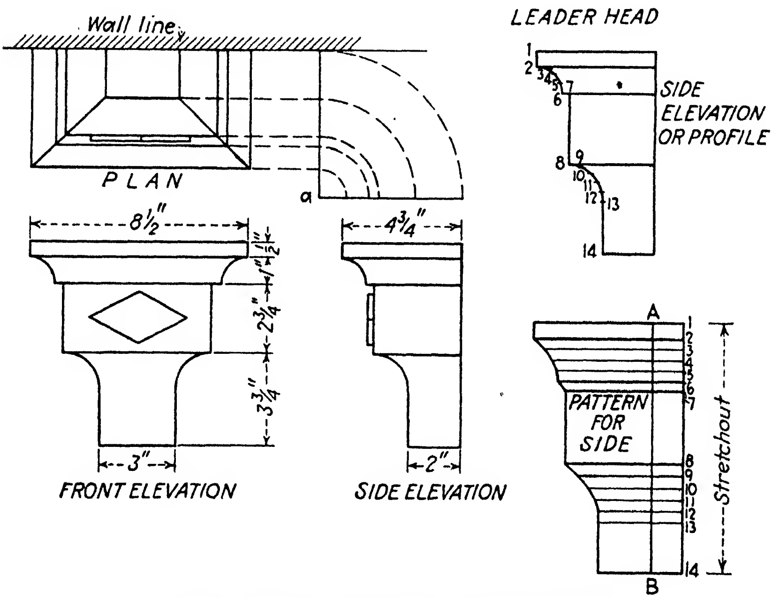


Fig. 42.—Square-return miter "conductor head."

seems to be no design too complicated to be made in sheet metal. In fact, many designs which are difficult or impossible in other materials are executed in sheet metal with complete satisfaction.

Sheet-metal cornices are made in a wide range of sizes and shapes as required in countless different uses. Usually the cornice is constructed in the shop in long lengths which are hoisted to the top of the wall of the building and put into place.

The principles applied to *parallel-line* developments, as explained in previous chapters, are also applicable to patterns for any molding so long as all of the members run parallel. If, however, two pieces of molding must be joined at an angle to form a corner, it is necessary to bisect the corner angle to get a so-called miter line (see page 11) so that the two ends of the molding will fit together. The term used in the sheet-metal shop for patternmaking on cornice work is miter cutting.

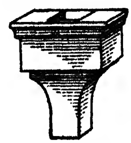


Fig. 42*a*.—Perspective view of Fig. 42.

A *carpenter* or *picture-frame maker* would probably require a 90-deg. angle for this type of work. He would therefore hold the molding in its proper position in a miter box and cut one piece to the right at 45 deg. and another piece to the left, also at 45 deg. By putting these together the 90-deg.

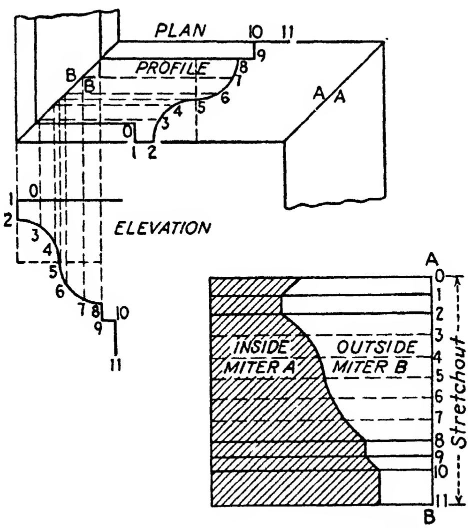


Fig. 43.—Inside and outside square-return miters.

corner would be constructed. The sheet-metal worker, on the other hand, must *develop* the corner at any desired angle on a flat surface. In this connection, he must be careful that the miter line is in its proper position on the profile or end view, so that when the two pieces are cut and joined the correct shape will be obtained and the front of the molding will face in the desired

direction. For instance, an error in the position of the miter line could produce a *face miter* such as would be used on the corner of a picture frame, instead of a *return miter* (Fig. 43*a*) similar to the molding around the wall of a room, where the ceiling and side walls meet.

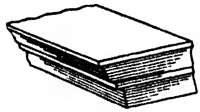


FIG. 43*a*.—Perspective view of outside square-return miter.

A patternmaker is generally required to draw full-size patterns in the shop, from small-scale detail drawings furnished by the builder. It is therefore important that he should understand how to draw the various types of moldings that are in general use.

SUPPLEMENTARY REFERENCE SHEET 3

This chapter treats of the fundamental principles of *parallel* forms as related to *cornice work.* Figures 42 and 43 show the development of a *square-return* cornice and a *square-return* ornamental leader head. Each of these drawings is made in the same way. Although a plan drawing is shown in Fig. 43, it is not actually required for the development of the pattern shape. As all square-return miters have a miter line of 45 deg., only the profile or edge view of the elevation is needed, and the plan view may be omitted; or the *plan* may be drawn with the profile inverted, as shown in Fig. 43, and the elevation omitted.

In Fig. 42 the plan, together with the front and side elevations of a conductor head, is shown. The side elevation is all that is required for the development of the pattern shape. If, however, the return miter is other than square, a plan drawing must be made. In Fig. 44 the profile is inverted in the plan, and because of this the elevation is not required, as the inverted profile is really the elevation drawn into the plan.

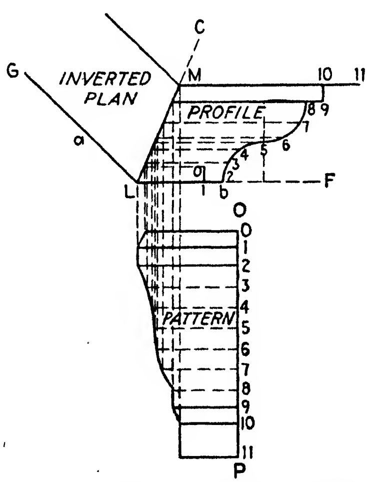


FIG. 44.—Miters not at right angles.

In the development of a reduced miter, Fig. 45, whether or not the miter is a square-return, the given profile of the main cornice must be drawn first and then be "inverted" into the plan. An additional view of the same profile is modified to obtain the true stretchout of the narrow side of the cornice.

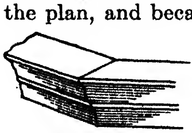


FIG. 44*a*.—Perspective of a cornice not at right angles.

In Fig. 46 is shown the development of patterns for face miters at different angles. The figures demonstrate that the elevation is the required view

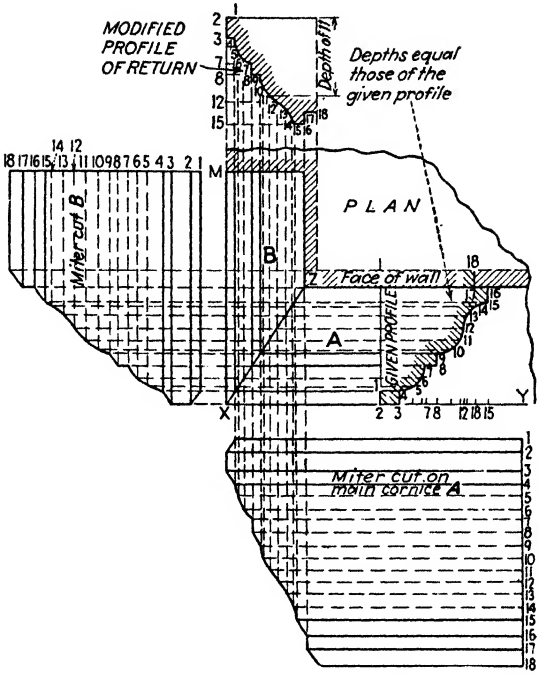


Fig. 45.—Reduced miter in a square-return cornice.

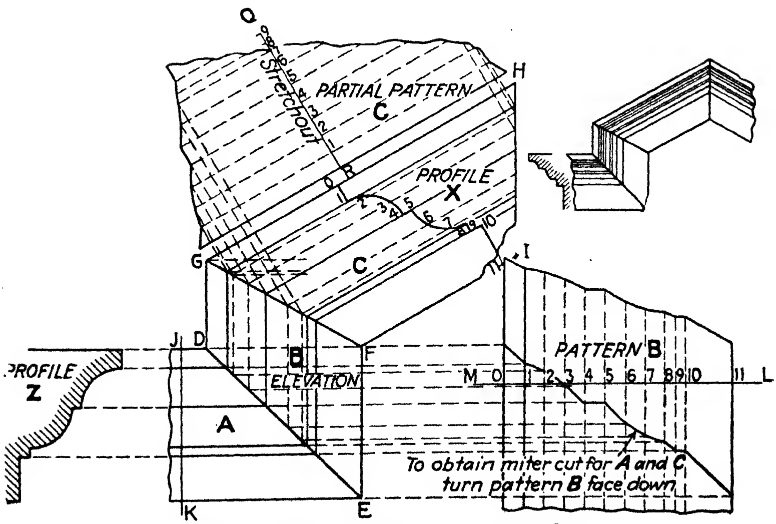


Fig. 46.—Face miters at different angles.

from which to obtain the patterns. The design shows two face miters, the lower part of which is a square-face miter, while the angle of the upper part is greater than a right angle.

A *face miter* is similar to a square-return miter. The only difference is that in face miters all the miters are on the face of the cornice, whereas the returns of square-return miters have perpendicular miters at the corners.

If the five problems given in this chapter are thoroughly understood, little difficulty should be encountered in any case that may arise in ornamental sheet-metal work, with the exception of curved moldings, which are not taken up in this book.

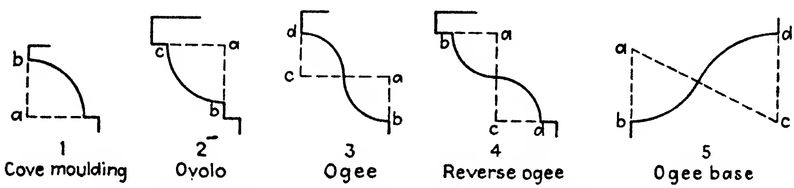


FIG. 47.—Common types of profiles used in cornice work.

The classical cornice profiles—cove mold ovolo, ogee, reversed ogee, and ogee base—are all Roman moldings, and are obtained by using the arcs of a circle. The drawings in Fig. 47 show how simple these moldings are in design.

PROBLEMS FOR PRACTICE

Instructions for the Development of Square-return Miters.—In Fig. 42 the plan of the front and the profile or side elevations of an ornamental *conductor head* are shown. Only the profile or side elevation, however, is actually required for the development of the pattern shape. The procedure is as follows:

1. Draw the profile or side elevation of the *leader head* and divide the curves into several parts.

2. Number each station on the curves and bends, as indicated by points 1 to 14. Extend horizontal lines lightly from these points to the back edge of the profile.

3. Directly under the side elevation, and at a reasonable distance below it, draw a line AB as marked.

4. On line AB lay off the vertical measurements taken from the profile as divided at points 1 to 14.

5. Draw lines at right angles from each point 1 to 14, and take off horizontal measurements from the width of the profile. From points 1 to 14 in the elevation, lines are projected to intersect similar numbers in the pattern shape. Lines drawn through these points complete the pattern shape of the side.

6. The front pattern has the same miter cut as the side pattern. In this case, if the conductor head were to be 8½ in. wide at the top and 3 in. wide at its bottom, the pattern would have to be measured accordingly between the miters for the front pattern.

7. As the conductor head has a straight back to fit against the wall of a building, the front elevation is the pattern for the back of the conductor.

8. When forming the pattern to shape, the side or front elevations should be cut out of metal and the pattern formed to the shape of the elevation.

9. To join the miters together no laps are necessary. The joints are butted together and soldered.

10. On large cornices laps are allowed on the miter joints, then soldered.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 43

Figure 43 is developed exactly like Fig. 42. Both are square-return miters and may be developed without the aid of a plan drawing.

The shaded part of the pattern shape represents an inside miter of Fig. 43 at *AA* in the plan. The outside miter pattern *B* forms the junction marked *BB* in the plan. In other words, the opposite cut of any miter produces the cut for an inside miter whenever required. Figures 43*a* and 42*a* show the perspectives of square-return miters, and Fig. 44*a* shows a perspective of a cornice, not at right angles.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 44

This problem does not require an elevation.

1. The angle *GLF* of the cornice, when bisected, makes the miter line *LM*.

2. The shape of the profile can then be drawn into the plan as shown and numbered from *O* to 11.

3. Horizontal lines may then be drawn from points *O* to 11, parallel to the line *LF*, which will intersect the miter line *LM*.

4. Draw the stretchout line *OP*, and place the points taken from the profile on this line from *O* to 11.

5. At right angles from the points of the stretchout of the line *OP*, draw lines intersecting similarly numbered lines drawn down from the miter line *LM* in the plan.

6. A line drawn through these established points completes the pattern shape for the miter line through LM.

INSTRUCTIONS FOR THE DEVELOPMENT OF PATTERN SHAPES—FIG. 45

Figure 48 shows a perspective of a reduced miter. One projection is 8 in., the other 12 in., a difference in projections of 4 in.

In a case of this kind, a plan drawing must be used. The given profile is drawn into the main cornice section as shown in the plan (Fig. 45).

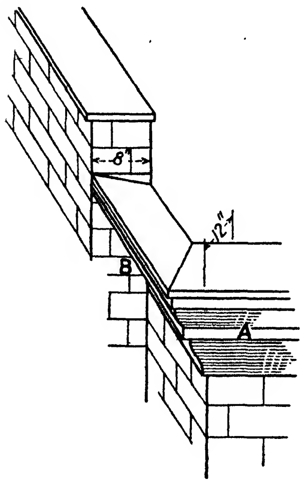


FIG. 48.—Perspective view showing a wide cornice intersecting a narrow cornice to form a mitered joint.

1. Where the width of the cornice MX intersects the width of the cornice YX at X, draw a line from X to Z, which gives the correct position of the miter line.

2. Divide the curves of the profile in section A into an equal number of parts; then number each part at the bends and curves as indicated from 1 to 18.

3. Project lines from points of the profile (1 to 18) horizontally and parallel to the line XY, intersecting the miter line at XZ.

4. As there is a difference in widths of the cornice, the main cornice profile must be modified. To do this, lines are extended from the points of the miter line, parallel to the line XM.

5. The various depths of the given profile are now taken along the line XY, as indicated by points 2, 3, 7, 8, 12, 18, and 15 in their respective order, and placed on the vertical line extended from XM at a reasonable distance above the plan.

6. Horizontal lines drawn from these established points will intersect similarly numbered points drawn vertically and extended from the miter line. New positions will now be established for drawing the curves. Lines drawn through the intersections will complete the modified profile.

NOTE: The depth of the profile does not change. Only the new positions for striking the arcs and widths at the bends change the aspect of the given profile.

7. The pattern shapes are now in order. The procedure for pattern shapes of the narrow side of the cornice *B* and the main cornice section *A* are developed exactly like the preceding problems, Figs. 43 and 44. The only difference is that there are now two stretchouts, one taken from the modified profile and the other from the given profile of the main section of cornice.

It is felt that further explanation is not necessary. Obtain the stretchouts and proceed as in Figs. 43 and 44.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 46

This case shows face miters at different angles, as they are used on the front of a building. The design and development are similar to preceding problems in this chapter. The procedure is as follows:

1. The angle of the cornice is drawn first as indicated by *J*, *D*, *G*, and *H*.
2. On a line extended from *JD* the desired profile is drawn, showing the shape of the cornice through *JK*.
3. As *JDG* is a right angle, the miter line at *DE* will be at 45 deg.

The miter line *H*1 is in a vertical plane. Since the depth of the cornice is of equal distance as at *JK* and *HI*, all the depths for sections *A*, *B*, and *C* are the same. Miters will be produced at *DE*, *GF*, and *HI* if lines *KE*, *EF*, and *FI* are drawn parallel to lines *JD*, *DG*, and *GH*.

4. The profile *X* may be inverted into the face, thereby eliminating the end profile *Z*.
5. Divide the profile in the usual way, and draw lines parallel to sections *A*, *B*, and *C*, intersecting all the miters.
6. Draw a horizontal line as marked *ML* at any reasonable distance between the space *F* and *E* of section *B*.
7. Place the stretchout of the profile on line *ML* as indicated from *O* to 11. Lines drawn at right angles extended on either side from points of the stretchout are intersected from similarly numbered points drawn horizontally from the miters *GF* and *ED*.
8. A line drawn through the points of intersection completes the pattern for section *B*. One cut of the miter as marked *A* will serve as a pattern for section *A*.
9. Anywhere between points *H* and *G* of section *C*, draw line *RQ* at right angles to *HG*.

10. Place the measurements of the profile as marked from *O* to 11 and from these points draw lines at right angles to *QR*, on either side of *QR* and parallel to *GH*.

11. From points of intersection at miters *HI* and *GF*, lines are extended at right angles to *GH*, intersecting similarly numbered points in the stretchout. A curve drawn between these points of intersection will complete the pattern shape for section *C*.

NOTE: To save time in developing the miter patterns, patterns for sections *C* and *A* may be obtained from the pattern for the middle section *B* by placing the pattern face downward.

EXERCISES

1. Make a scaled drawing to the dimensions of the leader head given in Fig. 42, and change the design so that ogee molding (Fig. 47) is used in place of cove molding.

2. Make a drawing and develop the patterns for a molding other than square-return, similar to Fig. 44. Instead of using an ogee curve, use the ovolo (Fig. 47).

3. Figure 48 shows an example of a narrow cornice intersecting a wider cornice to form the miter at the corner. Draw a similar cornice assuming your own dimensions.

CHAPTER V

RADIAL-LINE DEVELOPMENTS

Exercises in parallel-line development, as explained in preceding chapters, will now be followed by radial-line developments, which must necessarily be somewhat more academic in treatment than parallel-line forms. However, if the analysis of the development of a simple cone (or pyramid) and its intersections with other geometrical forms is thoroughly understood, the applications of the principles involved to cases that are related to conical forms of all kinds can be easily worked out. This chapter treats of cones, frustums of cones, raised covers, and irregular roof flanges.

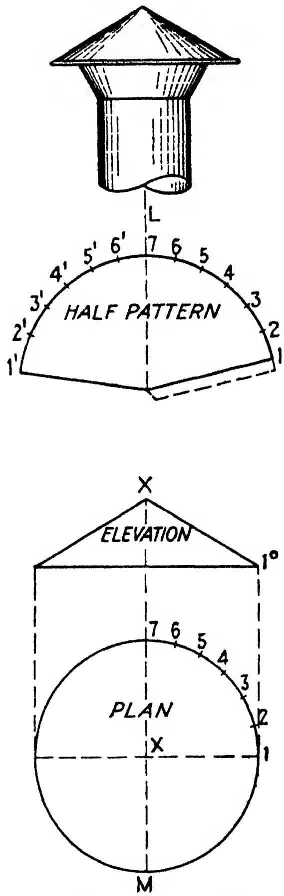


Fig. 49.—Chimney cap.

Pattern for Conical-shaped Chimney Cap.—Figure 49 shows a portion of a circular chimney that has a conical cap, of which the pattern drawing is to be made. First the elevation and plan drawings of the cone are to be made. Then one-quarter of the plan drawing of the cone, which, of course, is circular, is to be divided into six equal parts. With X as a center and the distance from X to 1° as a radius, draw a circle directly above the elevation drawing. Starting at the mid-point marked 7 and using spaces of the same size as those on the curve in the plan drawing lay off each division on both sides of point 7, that is, points on the curve from 1 to 1′. Then from these points (1 and 1′) draw a line to the apex, which completes half of the pattern shape of the cone.

Pattern of Frustum of Cone in Section of Chimney.—The pattern for a section of a chimney made in the shape of a frustum of a cone is developed in practically the same way as the cone in Fig. 49. Such a frustum in a chimney section is shown in

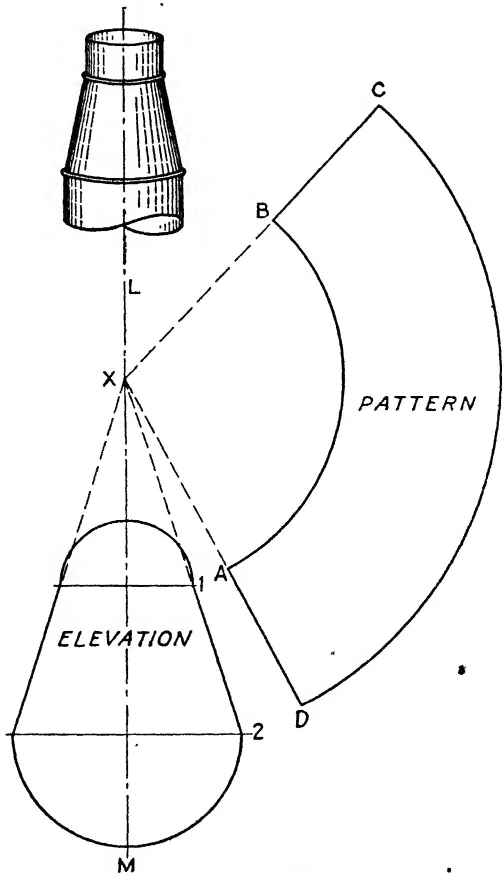


FIG. 50.—Reduced pipe (frustum of cone).

Fig. 50. In order to make the development of this surface, the center line *LM* is first drawn. In Fig. 49, the *profile* was divided and those division spaces were used in making the stretchout. The following method simplifies the means for obtaining the girth[1] of a cone or the frustum of a cone. The

[1] The *girth of a cone* is another name for the distance around, or the circumference at the base of the cone.

top and bottom curves of the frustum are drawn by taking X as a center and the distances $X1$ and $X2$ as radiuses. Any conveniently drawn line XD will cut the top curve of the frustum at A. Since the circumference of a circle is 3.1416 $\times$ diameter, the distance around the cone at its base, or its girth, can be easily calculated. If a strip of tin or cardboard is cut out to the length of this circumference, it may be placed on the drawing for the purpose of measuring from the position of point D and finding the length that the arc should be to point C.

Finally, in order to complete the pattern, a line is drawn from C back to the apex X, cutting the top curve of the pattern at B. It may be added that the *top curve* need not be actually measured. If the length of the *bottom curve* is accurately calculated and drawn, a line from a point such as C extending to the apex will always determine the correct girth of the curve on line AB. In large construction work, a steel rule may be used with sufficient accuracy for obtaining the true stretchout.

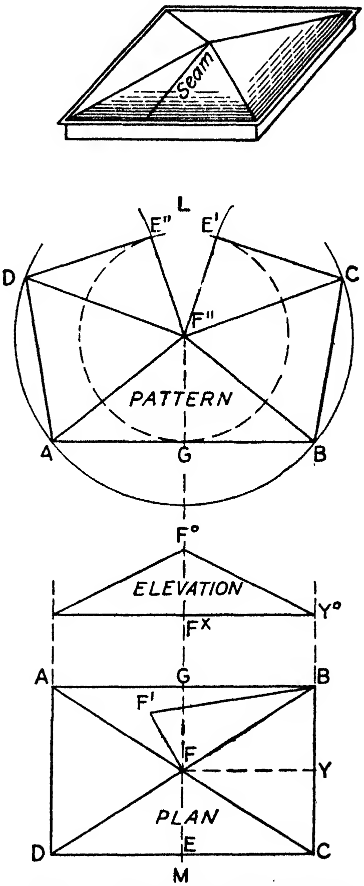


FIG. 51.—Pitched rectangular cover.

Pattern for Raised Rectangular Cover.—Plan and elevation drawings of a raised rectangular cover are shown in Fig. 51. After the figure was drawn, the perimeter, as shown in the plan drawing, was lettered A, D, E, C, B, and G. The next step was to draw lines from these points to the central point F. The letters marking points on the elevation drawing are F^x, Y°, and F°. The depth of the cover is shown in the same drawing by the vertical distance between F^x and F°, which is, of course,

located at right angles to line F, B in the plan drawing. If the triangle shown by F°, Y°, and F^x in the elevation is revolved in the plan drawing so that it is shown in its true length by the line connecting F' to B, then the distance $F'B$ is the true length of the edge of the cover FB, CF, DF, and AF in the plan drawing.

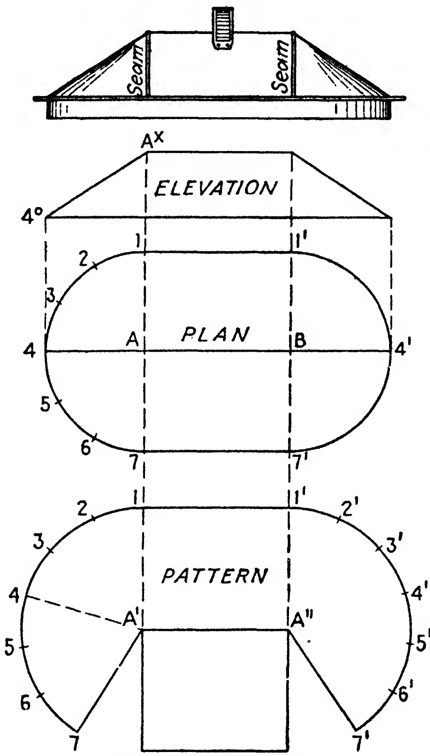


FIG. 52.—Oval cover.

For the pattern of this raised rectangular cover, in the necessary construction, the line element BF' is used as a radius. On the center line of the figure directly above the elevation, draw a complete circle with its center or apex at F''. Then extend the points marked A and B in the plan drawing to the circle of the pattern shape. Connect these two points with a line which at its intersection with the center line of the figure locates point G. Now using the distance BC as shown in the plan as a radius and points A and B in the pattern shape as centers, draw an arc cutting this construction circle at D and C. Then, if lines are

drawn connecting B and C and A and D, other lines can be drawn from the center F'' to the four points thus determined.

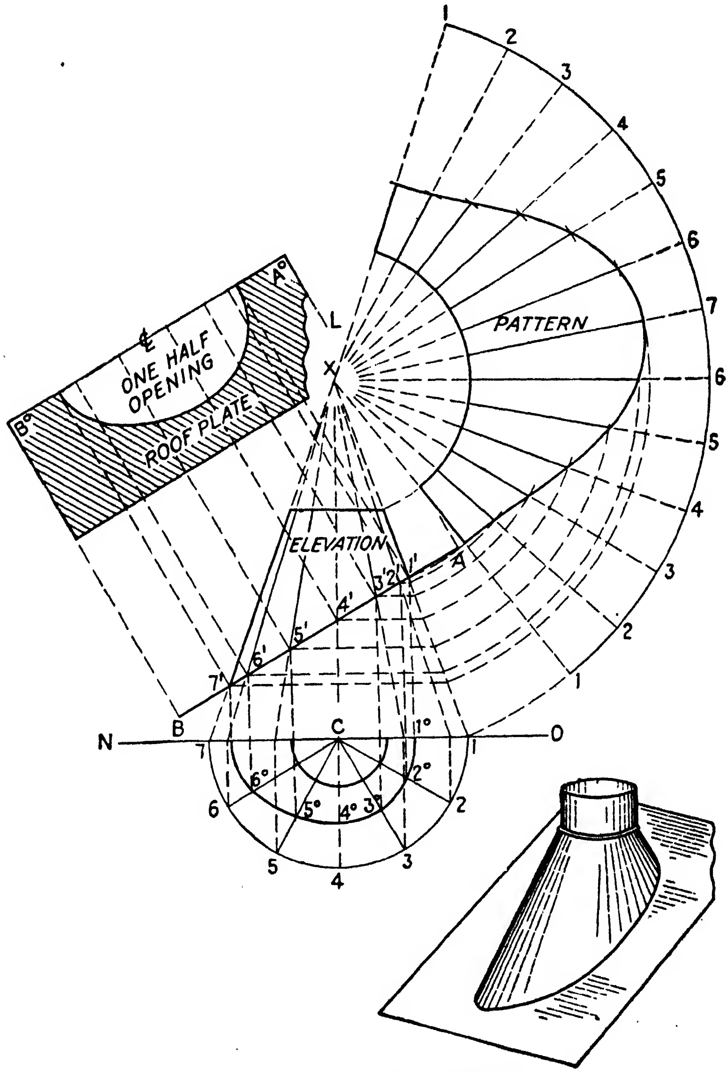


Fig. 53.—Tapering roof flange.

The next step is to draw arcs, with D and C as centers and the distance from B to G in the plan drawing as a radius.

Finally, with F'' as a center and with the distance between F'' and G as a radius in the pattern shape, draw an arc cutting the arc already made, locating points E'' and E'. Lines drawn to the center from these points complete the pattern shape.

Pattern of Oval-shaped Raised Cover.—The practical application of the development of a cone with a straight part added is shown in Fig. 52, which illustrates an oval-shaped raised cover.

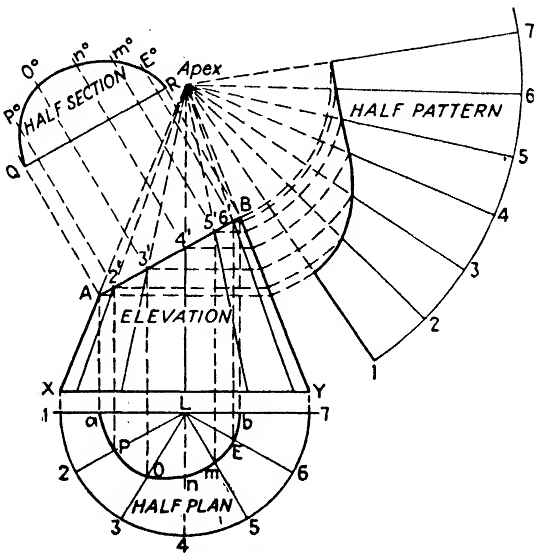


Fig. 54.—Irregular frustum of cone.

In the construction of the pattern, the first step, as shown in the figure, is to draw a semicircle, which is to be divided into six equal parts. Then, with the true size of the element of the surface ($A^x4°$) in the elevation drawing as a radius, and directly under the plan view with A' and A'' as centers, draw the necessary curves.

The first step in the development is to start with points 1 and 1′ and lay off the stretchout, as shown in the figure by lines between points 1 and 7, and between 1′ and 7′. The next step is to draw a line back to each of the apexes A' and A'' from points 7 and 7′. By adding the flat side between points A' and 1, as well as between A'' and 1′ to the opposite side of the figure, the complete pattern of the oval-shaped raised cover will be finished.

Pattern of Tapering Roof Flange.—An example of sheet-metal work, showing the use of a section developed on the cutting plane, is depicted in Fig. 53. The procedure in working out this case is like the one shown on Supplementary Reference Sheet 4, Fig. 57. In their practical aspects the two cases are almost identical, except that in Fig. 53 the upper part of the cone is cut off or truncated horizontally at the top but at the bottom is cut obliquely. In other words, the planes in this case are in the reverse position to those of Fig. 54.

SUPPLEMENTARY REFERENCE SHEET 4

Development of Irregular Frustum of Cone.—In Fig. 54, the elevation shows a cone in which the cutting plane is in an oblique position. This figure is sometimes called an irregular frustum of a cone. The lengths of the elements from the apex to the cutting plane are all different, and the section of the cone on line *AB* is thereby elliptical.

Make the cone 2 in. in diameter, 2½ in. high, with a cutting plane at an angle of 30 deg., drawn near the center of the cone.

1. To develop the half section, or true shape, on the cutting plane *AB*, it is first necessary to develop the exact shape of the cutting plane in the plan view. The large profile in the plan is divided in the usual way (six equal parts), and numbered from 1 to 7. Lines are drawn from these points to the center *L*. These are called radial lines.

2. Draw lines from 1 to 7 to the base of the cone, interesecting the line *XY*. Then draw them to the apex.

3. Where the lines cross *AB* at 1′, 2′, 3′, 4′, and 6′, they are brought down to intersect the radial lines in the plan at *a*, *p*, *o*, *n*, *m*, *e*, and *b*. A fair curve drawn through these points completes the elliptical shape of the inclined plane in the plan.

4. Extend lines drawn at right angles from the inclined plane *AB*, from points *A*, 2′, 3′, 4′, 5′, 6′, and *B*. At a reasonable distance, draw line *QR* at right angles to the extended lines.

5. Transfer the vertical distances in the plan from the horizontal center line 1-7, between *ab* at *p*, *o*, *n*, *m*, and *E*, to the measuring line *QR*, locating points $p°$, $o°$, $n°$, $m°$, and $E°$. A fair curve drawn through these points will complete the true section of the cutting plane *AB*.

6. To develop the pattern shape of the irregular frustum, take the radius from the apex to *Y*, and, with the apex as a center, draw a curved line of an indefinite length. On this curve, place the girth of the half profile from 1 to 7; and from these established points, draw lines to the apex.

7. To locate the top curve for the inclined part of the cone, lines are extended horizontally from points *A*, 2′, 3′, 4′, 5′, 6′, intersecting line *BY*.

NOTE: These lines are now all true lengths. From these points of intersection, curved lines are drawn, intersecting corresponding numbers in the pattern shape of the cone. A fair curve drawn through these points completes the half pattern.

NOTE: The work of developing the shape of the inclined plane is not required for development of the pattern shape and could be eliminated. However, as this has to be done so often in practice, it serves as a good lesson of developing a section on a cutting or inclined plane. Figure 53 shows a practical use of a developed section, which incidentally is exactly developed as explained for Fig. 54.

SUPPLEMENTARY REFERENCE SHEET 5

Underlying Principles of Radial-line Developments.—*A right cone* is a solid of one revolution. That is, if the plan of a right cone is drawn it will be a circle with a dot in its center, showing that all distances from the

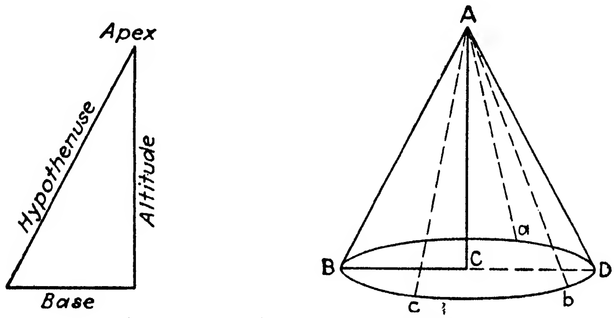


FIG. 55.—Surface elements of a cone.

center to any part of the curve are the same. If we assume the distance in the plan from the center to the curve is a base of a right-angled triangle and the altitude of the cone is the altitude of a right-angle triangle, then the hypotenuse or oblique side generates the sides of the cone and is of the same length anywhere about its apex (Fig. 55).

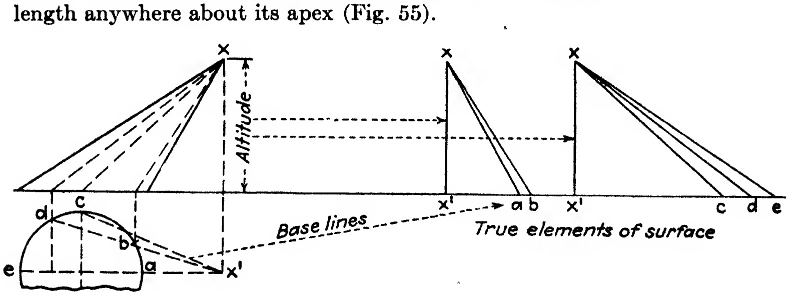


FIG. 56.—Scalene cone.

Element of Surface.—The generating line, that is, the hypotenuse of the triangle in any position in its circuit, is called an *element of the surface.* The entire surface of a right cone is therefore composed of elements all of the same length.

The side *AB* in any position during the revolution, as at *Aa*, *Ab*, *Ac*, etc., thus becomes an element of the conical surface.

When the apex changes position, that is, moves off the center, then all of the elements become changed and are of different lengths (Fig. 56).

In Fig. 56, all the lines in the plan view are base lines of a right-angle triangle; and as the altitude lies between parallel planes in the elevation, the same altitude will suffice for all the base lines. Since the true lengths of the base and altitude are known, the including line that is drawn (hypotenuse) is the true element of the surface for that particular line to be solved.

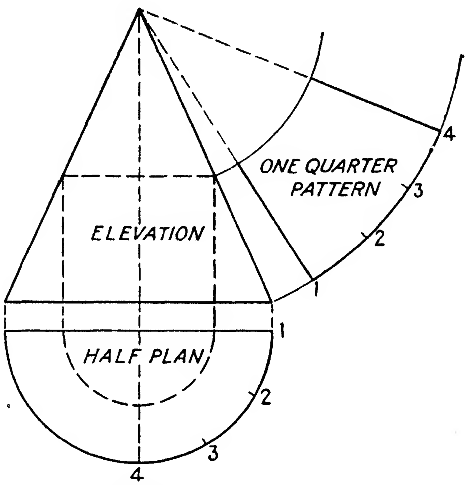


Fig. 57.—Frustum of a cone (truncated cone).

This is really a lesson in the principles of triangulation. One must understand it thoroughly in order to comprehend the radial-line method of developing. The radial-line method is a short cut for triangulation. If reasonable thinking is exercised and the radial-line method is thoroughly understood, then, when the triangulation method is encountered, little difficulty will be experienced.

The word element is a geometrical term, but becomes an extremely useful technical one, because the matter of obtaining the pattern shape for all conical forms depends principally upon the true lengths or elements of the surface.

Frustum of a Cone.—When the part of a cone between the top plane and the apex is taken away, the cone is said to be *truncated;* and that which remains is termed the *frustum of a cone,* the elements being the same length (Fig. 57).

EXERCISES

1. The drawings for a raised rectangular cover are shown in Fig. 51. The length and width are respectively 2 in. and 1¼ in. The height is ½ in.

Make similar drawings for the same type of rectangular cover, using the following dimensions:

Length = $1\frac{3}{4}$ in.
Width = $1\frac{1}{4}$ in.
Height = $\frac{3}{4}$ in.

2. The elevation and plan of an oval-shaped raised cover are shown in Fig. 52. The diameter of this conical-shaped cover is $1\frac{1}{2}$ in. and the height is $\frac{1}{2}$ in. The flat part between the semicircular ends in the plan measures $1\frac{1}{8}$ in. Make the necessary drawings of a similar oval-shaped raised cover to the following dimensions:

Diameter = $1\frac{3}{4}$ in.
Height = $\frac{5}{8}$ in.

with the flat part between the semicircular ends measuring $1\frac{1}{4}$ in.

CHAPTER VI

CLASSIFICATIONS OF INTERSECTIONS

This chapter treats of the intersections of cones and cylinders as they may be arranged in three different classifications. For all three classifications the pattern shape of the *cylinder* is developed in the same general way, but each classification must

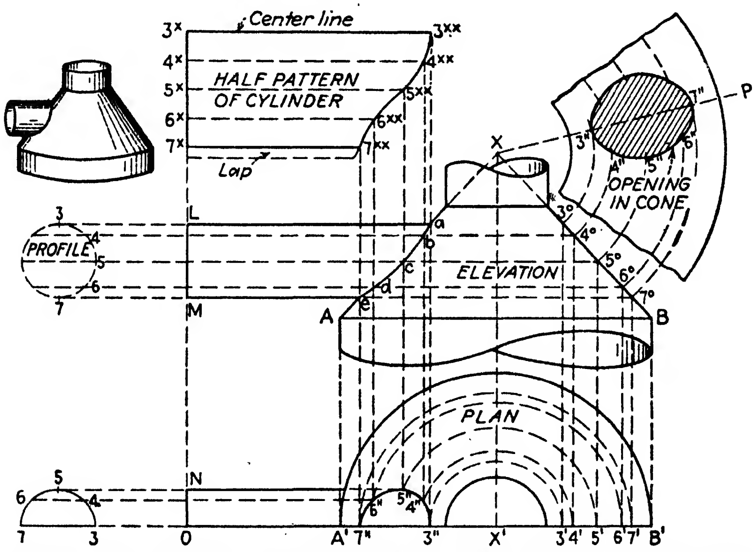


FIG. 58.—Cone intersected by cylinder placed at right angles to center-line axis of cone.

be treated separately in order to obtain the developed cutting plane of the cylinder where it intersects the cone.

The first of the three classifications is illustrated by Fig. 58, where the cutting plane is marked by the letters *e*, *d*, *c*, *b*, and *a*. In order to obtain the curved miter line[1] at the intersection of the cylinder with the cone, both the plan and the elevation drawings are required.

[1] A miter line is the line of juncture, and it may appear to be straight or curved in the elevation view.

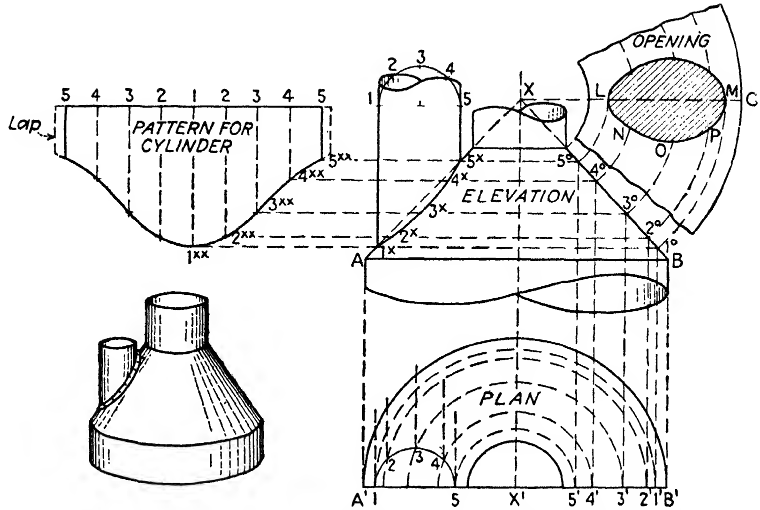


Fig. 59.—Cone intersected by a cylindrical pipe, parallel to the center-line axis of cone.

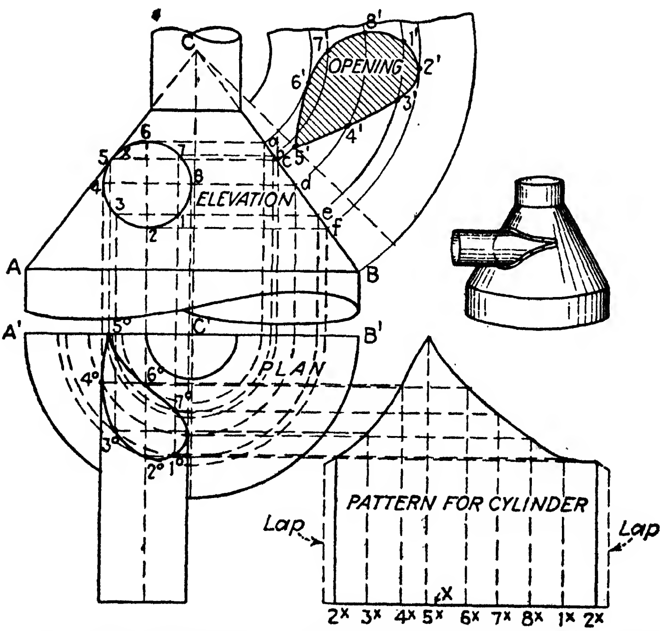


Fig. 60.—Cone intersected by cylinder off center and at right angles to center line.

Figure 58 shows a cone intersected at right angles by a cylinder. This represents the first classification referred to in this chapter. The second classification is represented by Fig. 59, which shows a cylinder intersected by a cone with its axis parallel to that of the cylinder, meaning, in this case, that the axis is vertical. The third classification is represented by Fig. 60, showing a cylinder tangent to one side of a cone at the point marked 5^x, and in this case the axis of the cylinder is at right angles to the axis of the cone.

As this chapter combines both the parallel and radial forms of developments (already explained), no supplementary reference pages are needed.

Developments of the Cutting Planes and Pattern Shapes for a Cone Intersected by a Cylinder.—Where the axis of the cone and that of the cylinder intersect at right angles, the line of intersection and the development of the pattern shape are obtained by following the instructions given:

INSTRUCTIONS FOR THE DEVELOPMENT OF PATTERN FOR FIG. 58

1. Draw the cone and mark the apex X; also mark the extreme points of its base A and B.
2. Draw the cylinder, keeping it close to the bottom of the cone. The length of the cylinder is optional; make the horizontal distances marked La and Me any reasonable length.
3. Draw the profile of the cylinder and divide half of it into four equal parts, numbering the divisions of the profile from 3 to 7.
4. As the cylinder is in a horizontal position, the opening at the *miter* must be shown in the plan. To develop this, place half of the plan of the cone a reasonable distance below the elevation, and mark the center line with the letters A', X', and B'.
5. Place the half plan of the intersecting cylinder as shown at N and O. Then divide the half profile and number each division from 7 to 3.
6. From points of the profile in the elevation 3-7, horizontal lines are drawn, intersecting the line XB and locating the points numbered 3°, 4°, 5°, 6°, and 7°.
7. From the above-established points, lines are projected downward, intersecting the center line of the cone in the plan at $7'$, $6'$, $5'$, $4'$, and $3'$.

8. From these points with X' as a center, draw semicircles intersecting at $7''$, $6''$, $5''$, $4''$, and $3''$ horizontal lines drawn from the profile in the plan from 7 to 3.

9. A line drawn through these points shows the correct shape of the cutting plane in the plan. Vertical lines erected from these points ($7''$ to $3''$), intersecting similarly numbered lines in the elevation, will produce the cutting plane at a, b, c, d, and e.

NOTE: The procedure for the cylindrical pattern needs no further explaining.

10. To obtain the pattern of the opening, draw circular lines from points 3° to 7°, using X as a center.

11. At pleasure, draw the line XP, cutting the circular lines $3''$ and $7''$, from which points the girth of the opening is measured as follows:

12. The irregular curved line in the half-pattern shape of the cylinder shows spaces marked 3^{xx} to 7^{xx}. When the cylinder is formed to shape, it must fit the opening in the cone. Therefore, these spaces must be true; and by using the space 3^{xx}, 4^{xx}, with $3''$ as a center, an arc is drawn cutting the radial line at $4''$. Proceed in this manner, using the next space, 4^{xx} to 5^{xx} with $4''$ as a center, which will establish the point $5''$. When all the points are located, a fair curve drawn through them completes the pattern shape of the opening.

INSTRUCTIONS FOR THE DEVELOPMENT OF PATTERN FOR FIG. 59

When a round pipe intersects a cone as is shown in Fig. 59, the curve of the miter must be developed as indicated by points 1^x to 5^x in the elevation drawing. Then the procedure for the pattern shape of the cylinder is like that for the end piece of an elbow. The specific instructions are as follows:

1. Draw a cone marking the apex X and the base AB.
2. Draw a half plan of the cone, locating points A', B', and X'.
3. Next draw the vertical pipe close to the bottom of the cone.

NOTE: If it is placed too high on the cone, the cylinder may not fit.

4. As the round pipe is in a vertical position, the plan of the cylinder is a circle. Draw a half circle and divide it into four equal parts, numbering the divisions 1 to 5.

5. Using X' as a center and $X'1$, $X'2$, $X'3$, $X'4$, and $X'5$ respectively as radiuses, draw semicircles, locating points $5'$, $4'$, $3'$, $2'$, and $1'$.

6. From these points ($5'$ to $1'$) in the plan, erect vertical lines intersecting the line XB in the elevation at $5°$, $4°$, $3°$, $2°$, and $1°$.

7. Horizontal lines are drawn from points $5°$ to $1°$, intersecting vertical lines extended from points 1 to 5 in the plan and locating 1^x, 2^x, 3^x, 4^x, and 5^x in the elevation.

8. A fair curve drawn through these established points completes the curved miter or cutting plane.

NOTE: The procedure for the pattern shape of the cylinder is the same as for the end piece of an elbow (page 16).

9. The pattern for the opening in the cone is found by drawing the radial lines of the cone pattern from points on the line XB, $5°$, $4°$, etc.

10. At pleasure, draw the line XC, which cuts the radial lines $5°$ and $1°$ at L and M.

11. Using the space on the irregular curve of the cylinder pattern marked 5^{xx} to 4^{xx} and with L as a center, draw an arc cutting the curved line $4°$ at N.

12. Using the next space in order 4^{xx} to 3^{xx} and with N as a center, draw an arc cutting the curved line $3°$ at O. In this manner, the pattern shape of the opening will be completed.

INSTRUCTIONS FOR THE DEVELOPMENT OF PATTERNS IN FIG. 60

1. Draw a cone as indicated by the base AB and the apex C.

2. Locate the intersecting pipe in the elevation, which is drawn looking straight at the object. The line of intersection is a circle tangent to the side of the cone.

3. Divide the circle into eight equal parts, and establish point 5, where the circle touches the cone, instead of at X. Number each part from 1 to 8.

4. To locate the shape of the cylinder in the plan, draw horizontal lines from 1 to 8 of the profile in the elevation, locating a, b, c, d, e, and f on the line CB.

5. Draw lines downward from points a, b, c, d, e, and f to intersect line $A'B'$. From these points of intersection, semicircles are drawn, with C' as a center.

6. Lines drawn down from points in the profile 1 to 8 will intersect the semicircular lines at 5°, 4°, 3°, 2°, 1°, 7°, and 6°. A fair curve drawn through these points completes the shape of the cylinder in the plan view.

7. As the intersecting round pipe is off the center of the cone, the stretchout of the whole circle must be taken out as shown, 2^x, 3^x, 4^x, etc. Erect perpendicular lines from these points which will intersect horizontal lines drawn from points 5°, 4°, 6°, etc. This completes the pattern shape of the cylinder.

8. The opening is found exactly as in the preceding cases (Figs. 58 and 59).

NOTE: In each of the three classifications of this chapter, the cone is truncated. This fact, however, does not affect the developments. It will be noticed that only part of the cone is developed, as Chap. V covered completely the cases of cones and their developments. Instructions for the development of a cone need not be repeated.

EXERCISES

The three problems given in this chapter show a round pipe intersecting a cone vertically and horizontally on centers (Figs. 58 and 59). Figure 60 shows a horizontal pipe intersecting a cone off the center. Make a drawing of the three problems illustrated, with the following dimensions:

Diameter of cone	= 4½ in.
Height of cone	= 3 in.
Diameter of cylinder	= 1½ in.

CHAPTER VII

INTERSECTIONS OF FRUSTUMS OF CONES WITH CYLINDERS

This chapter illustrates two different types of tee joints intersecting the frustum of a cone. Figure 61 shows a cylinder intersecting a right cone at an oblique angle. Figure 62 shows a frustum of a cone intersecting another frustum of a cone,

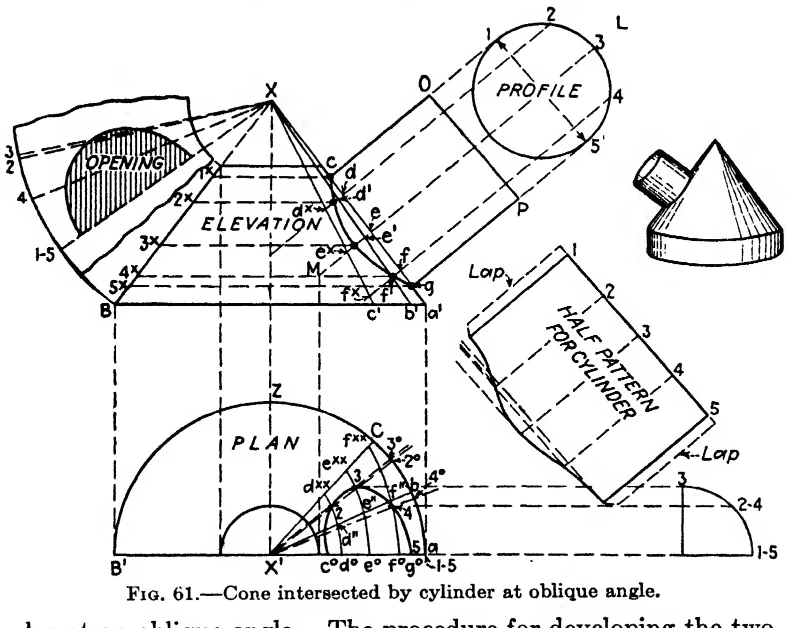


Fig. 61.—Cone intersected by cylinder at oblique angle.

also at an oblique angle. The procedure for developing the two cases is much the same. In both, the intersections are central, so that only half of the plan is required.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 61

1. The letters X, B, a' determine the outline of the cone.
2. The plan is drawn below the elevation, as indicated by points B', X', and a.

3. From point *e* on line *a′X* in the elevation, draw the center line of the cylinder (round pipe) at an angle of 45 deg., as at *L* and *M*.

4. Draw the diameter of the pipe as at points *o* and *p*. The length of the pipe is *co*.

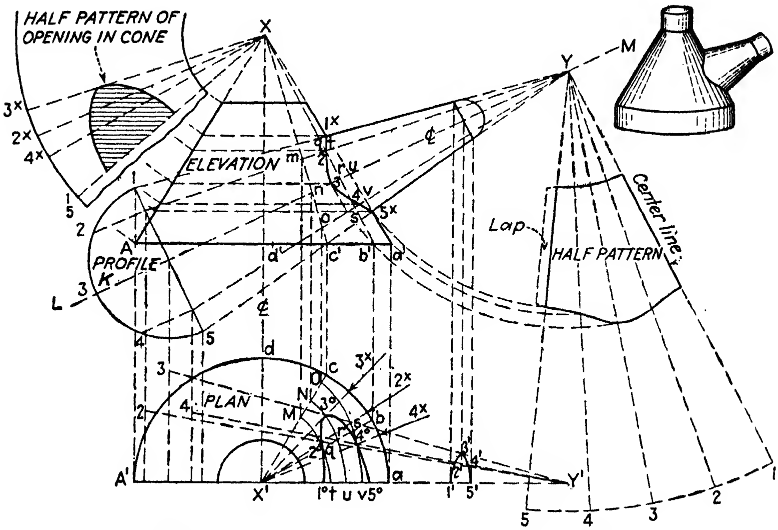


FIG. 62.—Right cone intersected by another cone at an oblique angle.

5. At a reasonable distance from line *op*, draw the profile, and divide it into eight equal parts. As only half of the profile is necessary, number each point of division 1 to 5.

6. Draw lines from points 1, 2, 3, 4, and 5 of the profile parallel to *oc* and *gp*, making the lines somewhat long and of random lengths.

7. In the plan, line *az* is bisected[1] to locate point *c*, and then line *ac* is divided into two parts, thus locating point *b*.

8. From points *b* and *c*, erect vertical lines to intersect the base of the cone in the elevation drawing at the points marked *c′* and *b′*.

[1] In Fig. 61 *az* was not actually bisected as stated in step 7. This, however, does not affect the drawing in any way. A 45-deg. angle may be divided into two *or more* parts, or a greater angle may be used and divided as shown in the plan drawing in Fig. 61. It was purposely divided this way, so that the points of the lines to be drawn in the following steps will not occur too close together, and so that each step may be clear.

9. Draw lines from c' and b' to the apex X.

10. Where the lines drawn from the profile intersect $a'X$, $b'X$, and $c'X$, as at points indicated with small arrows at d, d', and d^x, e, e', and e^x, f, f', and f^x, project lines into the plan, to intersect lines $X'a$ at $c°$, $d°$, $e°$, $f°$, and $g°$. Also intersect line $X'b$ as indicated at d'', e'', and f'', and line $X'c$ at d^{xx}, e^{xx}, and f^{xx}.

11. Draw a fair curve through the points obtained in this way, as at $f°$, f'', and f^{xx}; $e°$, e'', and e^{xx}; also $d°$, d'', and d^{xx}.

12. Draw the quarter profile of the pipe in the plan, and number it 3, 2, and 4; also 1 and 5 as indicated.

13. From these points horizontal lines are extended, intersecting the curved lines at 1, 2, 3, 4, and 5.

14. From these points, erect vertical lines to the elevation, intersecting the extended lines of the profile, indicated by the small circles drawn around the points of intersection.

15. A fair curve drawn through these points completes the cutting plane of the round pipe where it intersects the cone.

NOTE: The pattern shape of the round intersecting pipe is developed like a cylinder cut by a plane or the end piece of an elbow.

16. To obtain the shape of the opening, it is first necessary to find its girth. This is done by drawing lines from X' through points 2, 3, and 4 in the plan, thus locating the points indicated by arrows and marked 4°, 2°, and 3°.

17. Using X as a center in the elevation and XB as a radius, draw an arc representing the base of the cone.

18. At pleasure, draw a line from X, numbering the intersection at the curve of the base 1 and 5.

19. From points in the plan, 1-5, 4°, 2°, and 3°, in their respective order, place these spaces on the curved line drawn from XB, as indicated, 1-5, 4, 2, and 3.

20. From these established points, draw lines to the apex X.

21. Horizontal lines are then drawn from the intersecting points of the curved miter to line XB at 1^x, 2^x, 3^x, 4^x, and 5^x.

22. With X as a center, draw radial lines from these points, intersecting similarly numbered lines in the opening. A fair curve through these points completes the pattern shape of the opening.

Figure 62 is similar to Fig. 61. In Fig. 62 a cone intersects a cone at an oblique angle. The intersecting cone is drawn at

pleasure; that is, the size at the base of the intersecting cone at 1 and 5 is an assumed measurement. The bigger the measurement, the larger the opening will be on the line Xa', at 1^x and 5^x.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 62

1. Draw the elevation AX and a' of the cone with the horizontal base, as well as the half plan, $A'd$ and a.

2. Divide the line ad in the plan into three equal parts as at b and c, and draw lines from c and b to X'.

3. Erect perpendicular lines from a, b, and c, locating points at the base of the cone on the line Aa' at b' and c'.

4. Draw lines from these points to the apex X.

5. Draw the intersecting cone with its axis LM at any desired angle and of convenient length.[1] The diameter at the base is marked 1 and 5.

6. Draw the profile of the intersecting cone, and divide it into four equal parts, numbering the division points 1 to 5.

7. From points 1 to 5, lines are drawn to the apex y on the line LM.

8. Draw lines from the base of the right cone, that is, from the points c' and b' to X.

9. Lines intersect on line Xa'—at 1^x, t, u, v, and $5x$—and also on the line Xb' at q, r, and s. Also there are intersections on line Xc' at m, n, and o. Extend lines from these points into the plan drawing.

10. Points 1^x, t, u, v, and 5^x are located on line $X'a$.

Points q, r, and s are located on line $X'b$; and m, n, and o on line Xc' are extended to $X'c$.

11. A fair curve drawn through points m, q, and t, n, r, and u, and o, s, and v, in the plan, gives the correct position for the plan of the tee.

12. Locate Y' in the plan from Y in the elevation.

13. Whenever the cone is truncated, extend this view into the plan, and number it as shown at $1'$ to $5'$.

14. From Y' in the plan, draw lines through $2'$, $3'$, and $4'$, intersecting the radial lines at $2°$, $3°$, and $4°$.

15. A fair curve drawn through these points completes the plan of the intersecting cylinder (pipe).

[1] The diameter of the profile K is always an assumed measurement. The larger the diameter is, the larger the opening in the cone will be.

16. Erect lines from 1°, 2°, 3°, 4°, and 5° in the plan to intersect similarly numbered lines in the elevation; the intersections are at points 1^x, 2, 3, 4, and 5^x as shown.

17. A line drawn through these points completes the cutting plane.

NOTE: The opening is developed exactly like the one in Fig. 61.

NOTE: To develop the intersecting cone pattern the true elements of the surface must be developed by drawing lines from points 1^x, 2, 3, 4, and 5^x, of the cutting plane at right angles to the center-line axis of the intersecting cone *LM*, which will intersect the line *Y*5. The positions of the line will now be in order for developing the pattern shape, the instructions for which are given in steps 18, 19, and 20.

18. Draw the radius of the cone, using *Y* as a center and *Y*5 as a radius.

19. Place the girth on this line drawn from 1 to 5 in the profile, and draw lines from these points to the apex *Y*.

20. With *Y* as a center and radiuses from this center to points 1^x, 2, 3, 4, and 5^x, draw the curved radial lines, intersecting corresponding numbers in the pattern shape. A line through these points completes it.

EXERCISES

1. Make a drawing of a cone similar to Fig. 61 to the following dimensions:

Diameter of cone	=	5 in.
Height of cone	=	3 in.
Diameter of cylinder	=	2 in.
Angle of cylinder	=	30 deg.

Locate the center line of the cylinder 1½ in. up from the base of the cone, on the slant side.

2. Make a drawing similar to Fig. 62, where the center line of the intersecting cone penetrates the right cone at an angle of 30 deg.

Make a right cone 3⅓ in. in diameter and 3 in. high, assuming a suitable length of the center line *LM* and of the diameter of the profile *K*.

CHAPTER VIII

DEVELOPMENT OF SCALENE CONES

This chapter treats of the fundamental principles of the development of any scalene cone, whether or not it is truncated.

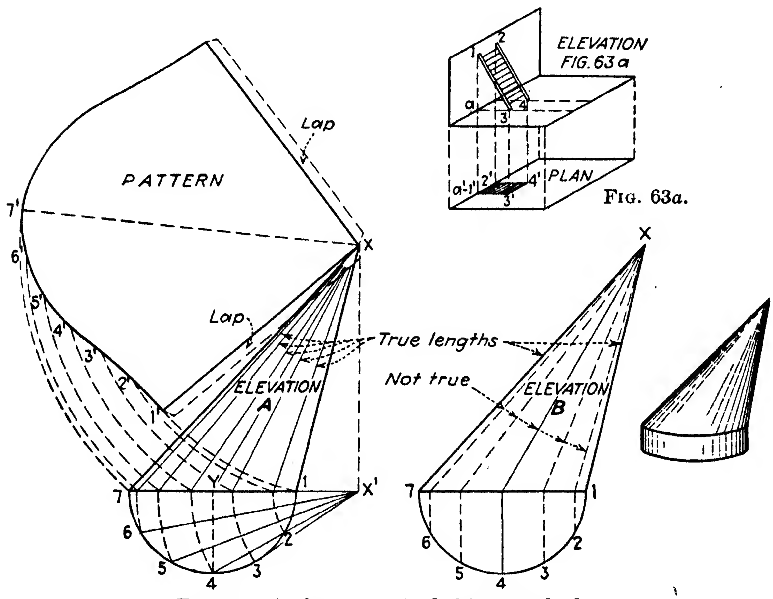


FIG. 63a.

FIG. 63.—Scalene cone (radial-line method).

Figure 63 shows simply a cone with its axis off the center, and Figs. 64 and 65 show practical applications of the development of Y branches by the *radial-line* method.

INSTRUCTIONS FOR THE DEVELOPMENT OF A SCALENE CONE

1. Draw the elevation of a scalene cone as in Fig. 63. The center line XY is to be at an angle of 60 deg. with the horizontal.

2. The next step is to draw the plan. In conical forms the plan is attached to the elevation. Extend the apex X to the

base of the cone, as at X'. Draw the profile of the base, and divide it into six equal parts.

NOTE: In the elevation B, the points of the profile are extended to the base and then drawn to the apex. Arrows indicate the lines that are not true lengths. The lines in this view show the true positions but not the true lengths.

3. In elevation A, using X' as a center and $X'2$, 3, 4, 5, and 6 as radiuses, draw curved lines to the base of the cone, intersecting the horizontal line drawn from 1 to 7.

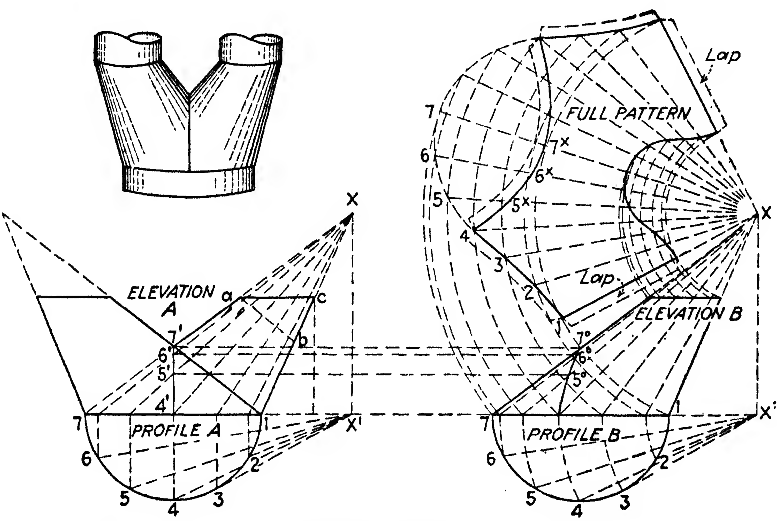


FIG. 64.—Two-way Y branch (developed from scalene cones).

NOTE: All the base lines of the plan are on the horizontal line; and, $X'X$ being the height, the including lines that are drawn from the base of the cone to the apex are now true lengths (as marked) of the elements shown in elevation B.

Elevation B is not required in the development of the lines. It merely shows that the lines marked $7X$ and $1X$ are true lengths, and gives the position of the others.

4. Since the base and the altitude form a right-angle triangle, the line $X'X$ is the altitude and $X'1$, $X'2$, $X'3$, $X'4$, $X'5$, $X'6$, and $X'7$ are the *base lines*. With X as a center, draw arcs from these base lines, using long sweeps.

5. At a convenient place, draw the line in the figure marked $X7'$, using a true space of the girth from 7 to 6 of the profile.

With 7 as a center in the pattern shape, strike the arc on the sweep at 6′. Continue in this manner and use 6′, 5′, 4′, 3′, 2′ as centers to locate the correct position for points at the base of the cone in the pattern shape.

6. A line drawn through these points and from 1′ to X will complete the pattern shape.

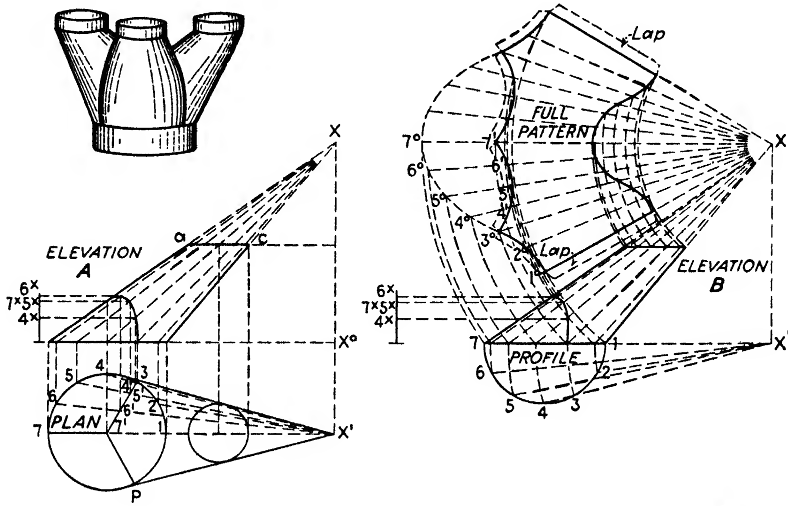


FIG. 65.—Three-way clustered Y branch (developed from scalene cones).

INSTRUCTIONS FOR THE DEVELOPMENT OF A Y BRANCH FROM SCALENE CONES AS IN FIG. 64

1. Divide the profile, and draw perpendicular lines to the base of the cone. From these points draw lines to the apex X. This gives the correct position of the surface lines. These lines, however, are not true lines.

2. Where the left half of the cone penetrates the right half, the intersection marked 7′ is the height of the *junction*, or joining line of the Y branch.

3. Where the oblique lines cross the vertical *junction*, number the intersections as at 6′, 5′, and 4′.

4. Develop the surface lines in elevation B as instructed in Fig. 63.

5. Lines are then drawn horizontally from points of the elevation A at 7′, 6′, 5′, and 4′, intersecting similarly numbered oblique lines at 7°, 6°, and 5° in elevation B.

6. The procedure for the pattern shape of the scalene cone is exactly like that for Fig. 63.

7. Lines are drawn from the base of the curve in the pattern shape from points 7, 6, 5, 4, 3, 2, and 1 to the apex *X*.

8. Curved lines drawn from points 7°, 6°, and 5° intersect the radial lines of the pattern at 7^x, 6^x, 5^x, and 4. A curved line drawn through these points completes the curve of the vertical junction in the pattern shape.

9. Curved lines drawn from the points of the truncated part in elevation *B* to the similarly numbered radial lines in the pattern shape complete the whole pattern for one branch of the Y.

In Fig. 65 two elevations are required, drawn at a 60-deg. angle. The diameter of the truncated part is at *ac*.

INSTRUCTIONS FOR THE DEVELOPMENT OF A THREE-WAY Y BRANCH AS IN FIG. 65

1. Draw the plan of the base and divide it into three parts, as at 7, 3, and *p*. Lines drawn from these points to the center of the circle represent the miters for the three branches of the Y (elevation *A*).

2. Divide one-half of the profile into six equal parts. Locate *X* in the plan as marked *X′*. From this point draw lines to points of the profile numbered 1 to 7.

3. Erect perpendicular lines from points 1 to 7 in the plan to the base of the cone, and from these intersections draw oblique lines to the apex (elevation *A*).

4. From points of the junction in the plan 7′, 6′, 5′, and 4′ erect lines to similarly numbered oblique lines in the elevation, as at 6^x, 7^x, 5^x, and 4^x. These points give the position of the junction.

5. In elevation *B* draw the half profile and divide it into six equal parts, as numbered from 1 to 7. Using *X′* as a center, draw arcs from these points to the base of the cone and then extend them to the apex *X* (elevation *B*).

6. From the vertical depths of the junction points (6^x, 7^x, 5^x, and 4^x) draw horizontal lines, intersecting similarly numbered lines in elevation *B*. A curved line through these points completes the developed junction.

7. The pattern shape now is developed exactly as for Figs. 63 and 64.

In Fig. 66 a quick method is given for developing the pattern shape for the irregularly shaped section of a three-piece round offset. The end sections are developed by the *parallel-line* method, which is explained in preceding cases. This method

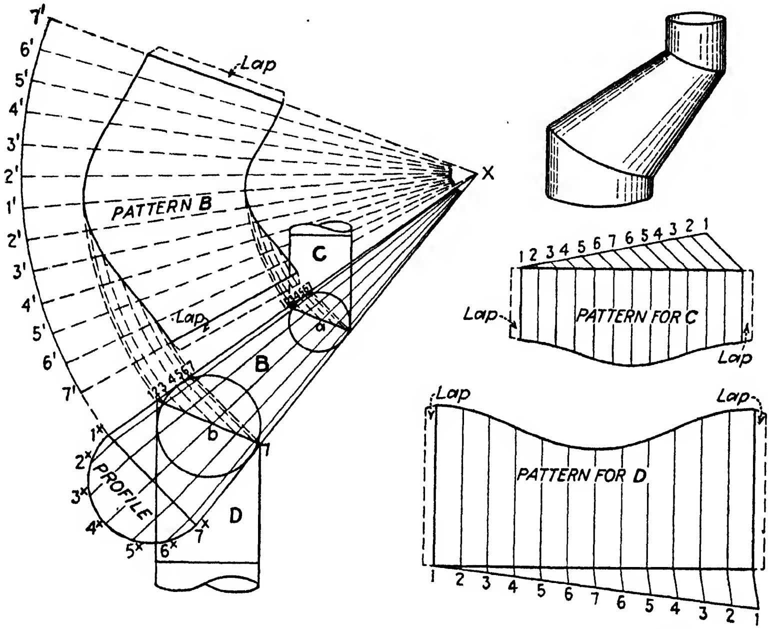


Fig. 66.—Radial-line method of developing round reduced offset.

simplifies the laying out of any reduced offset where and if an apex is easily obtained.

Note: In designing a reduced offset to be developed by the *radial-line* method, the miters are not found by bisecting the angles, as is usually done in offsets.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 66

1. Construct the offset of the same size horizontally and vertically, which will make a 45-deg. angle. Extend a line through points *a* and *b* (Fig. 66), making it long enough for an apex to be reached.

2. At point *a* draw a small circle and at *b* a larger circle, as shown. These circles represent the diameters of the cylinders or pipes.

3. Lines are then drawn tangent to the circles, locating the apex at X.

4. Draw the elbow ends CD, making them also tangent to the circles intersecting the oblique lines at 1 and 7. The miters are thus slightly off the centers of points a and b.

5. A line drawn from 1 to 7 at both junctions gives the correct position of the miters.

6. Extended lines are drawn from X through points 1 and 7.

7. Draw the profile, and divide it into six equal parts as indicated by the points from 1^x to 7^x. Lines are drawn from these points to the base of the cone at right angles to it. From these points, lines are drawn to the apex, cutting the junction at points 1 and 7 of both miters.

NOTE: The diameter of the profile may be conveniently placed on the extended lines.

8. From these intersections of the miters, lines are drawn at right angles from the center line ab to the outer edge of the cone as marked by points 1 to 7.

NOTE: When a cutting plane is "inclined" on a right cone, the true lengths of the lines must be found. By squaring the lines from the intersections, as described in step 8, and drawing them to the other edge of the cone, true lengths and a new position from which radial lines are drawn into the pattern shape are obtained.

9. Using X as a center and $X1$ as a radius, make a long sweep.

10. At a reasonable distance from the elevation, draw the line $X1'$.

11. Step off the girth from points $1'$ to $7'$, and from these points draw lines to the apex X.

NOTE: The stretchout is found the same way as for a cone

12. By drawing arcs from the established true lengths from points 1 to 7 in the elevation to similarly numbered lines in the pattern shape, the pattern for the irregular section B is completed.

SUPPLEMENTARY REFERENCE SHEET 6

The Oblique Cone

An oblique cone is one in which the apex is not perpendicularly over the center of the base. This being so, one side of it will be longer than the other, and the lengths of all the generating lines will be unequal. For this reason,

it cannot be marked out with one radius from a common center but is really produced by *triangulation.*

Figure 55, Chap. V, shows the development of the surface elements of a right cone; and, as all of the elements of the cone are of the same length, only one radius is required for the pattern shape. Figure 56 in the same chapter shows an oblique cone, and illustrates that all the elements are of different lengths.

The object of the *scalene cone* (Fig. 63) is to show the method by which the more difficult patterns required by the metal worker may be obtained by means of triangles. It is not claimed that this is the best method to use in the development of every pattern, but it is suggested as an alternative method for the simpler irregular forms that are conical in shape. This method is the only possible one for use in working out the more difficult cases which are met with in dealing with all other forms that are irregular in shape. The next eight chapters will fully cover the triangulation method.

The scalene cone merely introduces the triangulation method in this chapter. The radial-line method for developing the scalene cone is a short method of triangulation.

Figure 63*a* shows a ladder resting against a wall. From the front the ladder is not seen in its true length, but the height reached is shown. In the plan, only the distance the foot of the ladder stands from the wall is seen. If, however, a side view or elevation of the ladder and wall is drawn, all dimensions shown in Fig. 63*a* are obtained; that is, height, plan length, and the true length of the ladder itself.

In triangulation, two dimensions are always given. The plan view always shows the base dimension of a right-angle triangle; the elevation always shows its height; and the including line which is drawn forms a right-angle triangle of which the hypotenuse is the true length of the line to be found. This is exactly what is done in finding the true lengths of the elements of the surface in a scalene cone. The explanation for developing the scalene cone will be found on page 66.

In Fig. 64 two elevations of a scalene cone are to be drawn, as indicated by *A* and *B*. Draw the elevations at a 60-deg. angle. The diameter of the truncated part is at *ac*.

EXERCISES

1. In elevation *A*, Fig. 64, the oblique legs of the Y branch have parallel planes. That is, the top plane *AC* is parallel with the bottom plane 1-7.

Design and develop the pattern shape for a similar figure when the top plane is inclined as at *AB* (elevation A, Fig. 64) and the center line angle at $4'X$ is at 60-deg.

2. Make a similar drawing for Fig. 65 to the following dimensions:

Large diameter	=	2¼ in.
Small diameter	=	1¼ in.
Length of center line	=	6 in.
Angle of center line	=	60 deg.

CHAPTER IX

TRIANGULATION METHODS

This chapter introduces the triangulation methods of developing pattern shapes. This and the following chapters will include all the principles, such as designs, connected with the triangulation methods. In Supplementary Reference Sheet 7 (page 82), *four rules* are given that should be of special help in the construction of any irregular-shaped object, and should be consulted often.

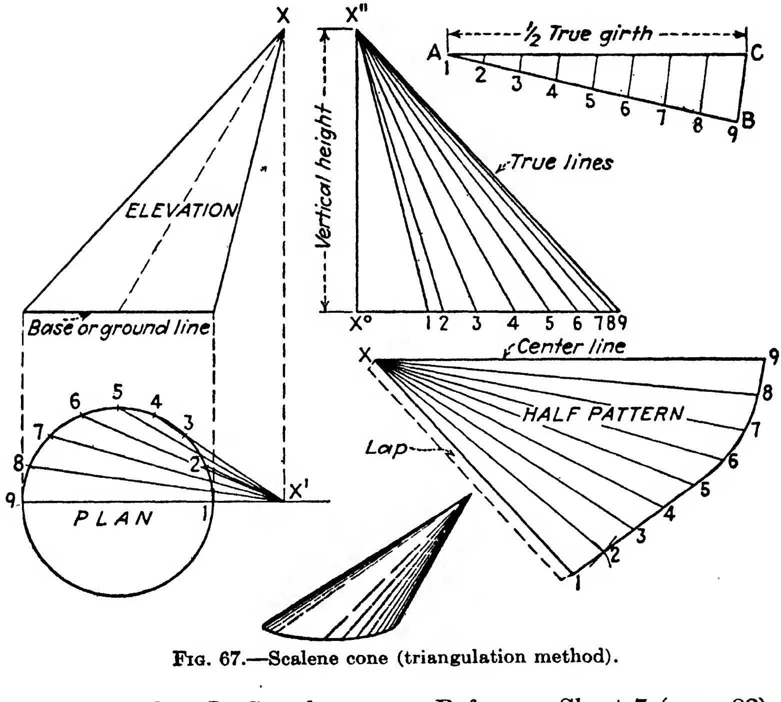


FIG. 67.—Scalene cone (triangulation method).

This chapter covers Rules 1 and 2 in Supplementary Reference Sheet 7 (page 82). In this chapter, five cases are given. All of them may be developed without the aid of the elevation. As

their planes are horizontal and parallel in the elevation, only one altitude is needed. The lines in the plan represent the surface elements and are base lines of a right-angle triangle. Therefore, if the height and base of a right angle are known, the including line that is drawn completes a right-angle triangle the hypotenuse of which is the true length. By making a

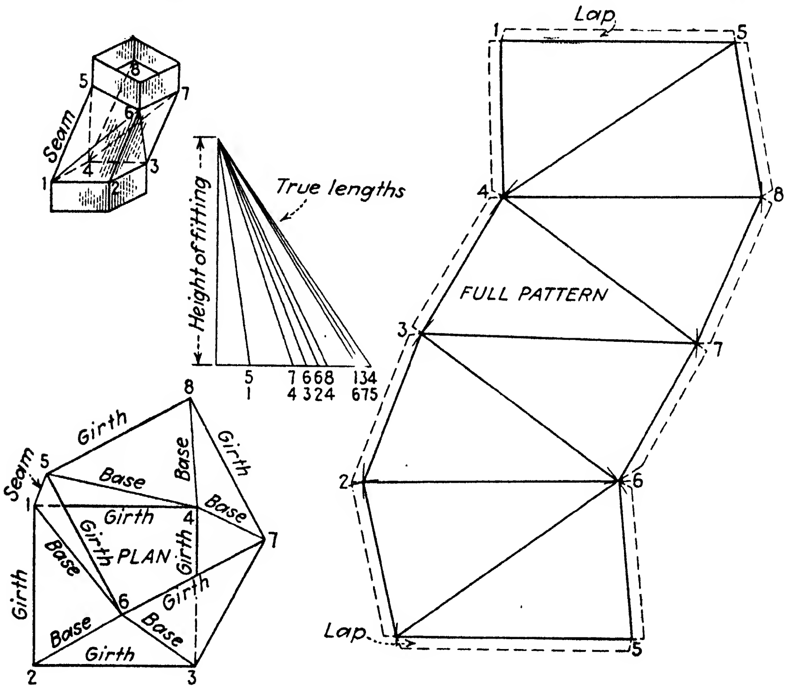


FIG. 68.—Twisted square pipe.

diagram of such triangles the true lengths of all the surface lines are obtained.

In Figs. 69 and 71 two ways of developing surface lines are shown: (1) as just described, and (2) the *simplified method.* Both methods produce the same result in all cases where the halves are symmetrical. The simplified method is introduced in this chapter to establish familiarity with both ways of developing true lines.

In Chap. X the simplified method will show how a difficult case is made easier by developing the surface. The instruction and reference sheets of this chapter fully explain this method.

In Chap. VIII a typical cone was developed by the *radial-line* method. The development is repeated here to show the application of the *triangulation* method.

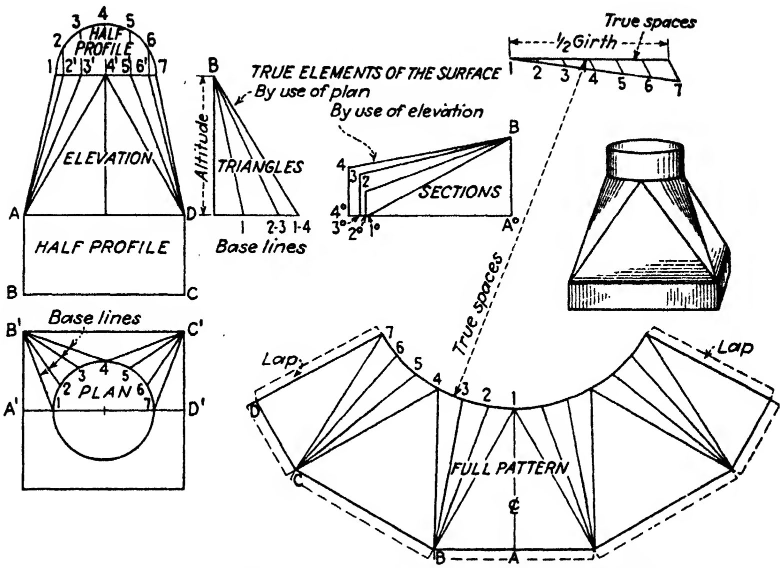


FIG. 69.—Square-to-round transition (symmetrical halves).

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 67

1. Draw the base of the required cone with the center line at an angle of 60 deg.

2. Directly below the base or ground line, at a reasonable distance below the elevation, draw the plan. Locate the apex X' by extending a line from X downward in the elevation, at right angles both to the base of the cone and to the center line of the plan.

3. The plan shows that the halves are alike, so that only one-half of the circle in the plan needs to be divided. In this case eight divisions or *spaces* are used. Number each division point from 1 to 9, and from these points draw lines to the apex X'. This completes the plan view and gives the correct position of lines as they are to be developed.

NOTE: All of the lines shown are in right-angle triangles; that is, the vertical height will have to be visualized at X', and the lines in the plan will

be the base lines. The (hidden) hypotenuse, being directly over these lines, will appear in the plan as of the same length. Perhaps a better way to see this would be to look directly down upon a right-angle triangle placed on a table in a vertical position.

4. Erect a line representing the vertical height marked $X°X''$. Lines in the plan from X' to 1 through 9 are placed on the horizontal line drawn from $X°$, thus locating points 1 to 9 inclusive.

NOTE: Instead of taking out individual triangles, all of the base lines are drawn to the same altitude X''. This method will prevail throughout the book to save time and space.

5. Compute the girth (3.1416 × diameter) and divide this line, obtaining a true division or space to be used for the circumference in the pattern shape.

6. To start the pattern, take the true length of the line in the diagram marked $X''1$, and arrange it at any convenient place on the paper to be used for the drawing.

7. With X'' as a center and $X''2$ as a radius, draw an arc in the pattern shape. Using a true division or space on the girth, with point 1 as a center, draw another arc intersecting and locating point 2. In this manner, all the true lines are placed in the pattern shape in the same way.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 68

This case shows a twisted square pipe. A plan must be shown for this type of fitting, as the halves are not the same. The elevation is not needed, as only one height is necessary. (See Supplementary Reference Sheet 7, Rule 2.)

1. Draw the plan, showing the amount of twist and offset the pipe is to have.

2. Number the corners of the bottom profile in the plan 1, 2, 3, and 4, and the top profile 5, 6, 7, and 8. *These lines represent the girth* (page 13). Draw lines from 5 to 1, 6 to 1, 6 to 2, 6 to 3, 3 to 7, 7 to 4, 4 to 8, and 4 to 5. *These are the surface lines to be developed.*

3. Erect a vertical line representing the vertical height of the twisted square pipe.

4. From this vertical height of the twisted square pipe, draw a horizontal line which will represent the base of a right angle. On this line place the base lines of the plan as indicated at points 5 and 1, 7 and 4, 6 and 3, etc. Lines drawn from these points

converge at one point, forming a series of right-angle triangles, the hypotenuse of which is the true length.

5. To start the pattern shape, take the true length of the line 1-5, and place it at any convenient place on the paper, allowing room for the pattern.

6. With 1 as a center and 1-6 as a radius taken from the true lengths, draw an arc. Now, using the girth line 5-6 in the plan as a radius and with 5 in the pattern shape as a center, draw an arc. The intersecting arcs will locate point 6.

7. To locate point 2 in the pattern, use the true length 6-2 as a radius, and from point 6 in the pattern draw an arc. From point 1 in the pattern, using the girth space 1-2 in the plan as a radius, draw an arc. The intersecting arcs will locate point 2.

8. To locate point 3 in the pattern, use the true length 6-3, and with 6 as a center, draw an arc. Using the girth space 2-3 in the plan as a radius and the point 2 in the pattern shape as a center, draw an arc. The intersecting arcs will locate point 3.

The procedure for placing the remaining true lines in the pattern shape is exactly like the preceding steps (6, 7, and 8).

The sketch of Fig. 68 shows the elevation in perspective and the elements of the surface numbered in their respective positions.

Square-to-round Transition on Center

This figure shows a square pipe joined to a round one. The plan shows that the halves are the same, and either view will be sufficient to produce the true lengths without the aid of the other. Two diagrams of true lengths are shown. The one showing a *diagram of triangles* is developed by using the plan without the aid of the *elevation.* The other *diagram shows sections.* The lines of this diagram are developed without the aid of the *plan.*

Either of these methods will produce the same results. However, the diagram using the plan method takes up less room, and is preferred in practice on all straight fittings such as are treated in this chapter.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 69

Draw the center line in the elevation, equal to the height of the transition. Draw the half profiles of the round and square ends and place them in position. Divide the circular profile, and number it from 1 to 7. Mark the square profile *A*, *B*, *C*, and *D*.

1. Place the lines in position in the elevation, and directly below the elevation (at a reasonable distance below the ground line) locate the plan.

2. Place the lines in position as indicated in the plan. The order of lines in both the plan and the elevation will now read A' to 1; B' to 1, 2, 3, and 4; C' to 4, 5, 6, and 7; and 7 to D'.

NOTE: In the elevation, $B1$ is directly over $A1$. Close examination of the plan shows this relation.

It will be noticed that only half of the lines are developed, as all of the quarters are alike.

3. If the true lines are to be developed by using the plan, erect a line equivalent in length to the straight height. From the base of this elevation extend a horizontal line to form a right angle.

4. Take the base lines in the plan from A' to 1, B' to 1, 2, 3, and 4, and place them on the base of the right angle. Draw lines from these points converging at the apex or height of the transition, thus forming a series of right-angle triangles. Incidentally, lines 2 and 3 have the same length, as well as lines 1 and 4.

5. If the lines are developed by sections, only the elevation need be drawn. To develop the lines, first draw a line equivalent to the distance from A to B in the half profile. With A as a measuring point, the lengths in the elevation are taken from A to $1'$, $2'$, $3'$, and $4'$, and placed on the horizontal line from $A°$, locating points 1°, 2°, 3°, and 4°.

6. Erect perpendicular lines from these last points, and place the vertical distances from the center to the outer edge of the profile, as at $2'$-2, $3'$-3, and $4'$-4 on the vertical lines at 2°-2, 3°-3, and 4°-4. Lines from these points drawn to B complete the diagram of true lines, which should equal the true lines developed from the plan method. This check shows that the two methods are equally satisfactory.

7. To make the pattern shape, assume that the elevation is not shown at all. Erect a center line equivalent to the true length from A to 1. Using the girth of the plan from A' to B' on either side of A, point B can be located in the pattern shape. Draw a line from B' to 1.

8. Using the true length from B to 2 as a radius and with B as a center, draw an arc. With a true space of the round end

as a radius and 1 as a center, draw another arc. The intersecting arcs will locate point 2.

9. Points 3 and 4 are located in the same way. To locate C in the pattern shape, take the length of the girth $B'C'$, and with B as a center, draw an arc. Using the true length of the line $4B$ (which is the same as $4C$) and with 4 as a center, draw a radius with arcs intersecting at C.

10. Points 5, 6, and 7 are located in the same way as points 1, 2, 3, and 4.

The true length of the line between 7 and D is the same as that between A and 1. Using 7 as a center, draw the radius. With C as a center and a radius equal to $C'D'$ in the plan, a radius is drawn intersecting the arcs at D. Lines drawn through all points as indicated will complete the pattern shape without laps.

Square-to-round Pipes, Off Center.—This case shows a square pipe joined to a round one. They are off the center in two directions. In all cases of this kind it is necessary to divide the whole circle, as all quarters are different. Their true surface elements will also be of different lengths.

Rule 2 (page 82) is applied to this case. As the plan shows, the halves are not symmetrical, and the vertical height has only one measurement. Therefore no elevation is required.

The base lines in the plan, in conjunction with the altitude, are developed as in Figs. 68–69, thus forming a diagram of triangles.

The development of the pattern follows the same procedure as for Figs. 68–69, except that all of the elements are different and the pattern shape is not started from a vertical center.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 70

1. Draw the plan with a square base, assuming that the amount of offset required forms two straight heights at G, M, and D.

2. Divide the circle and arrange the lines as indicated.

NOTE: The elevation is not required.

3. Develop the true lines as previously instructed in Figs. 68–69.

4. To start the pattern take the distance from 2 to 4 in the plan, and draw a horizontal line at a reasonable distance from the plan.

5. Using the true lengths (4*A* and 2*A*) with 2 and 4 as centers, draw intersecting arcs, locating *A*. Draw a line from *A* to 4 and from *A* to 2.

The procedure for the rest of the pattern is carried on in the same way as in Fig. 69, except that all the lines of the surface are of different lengths.

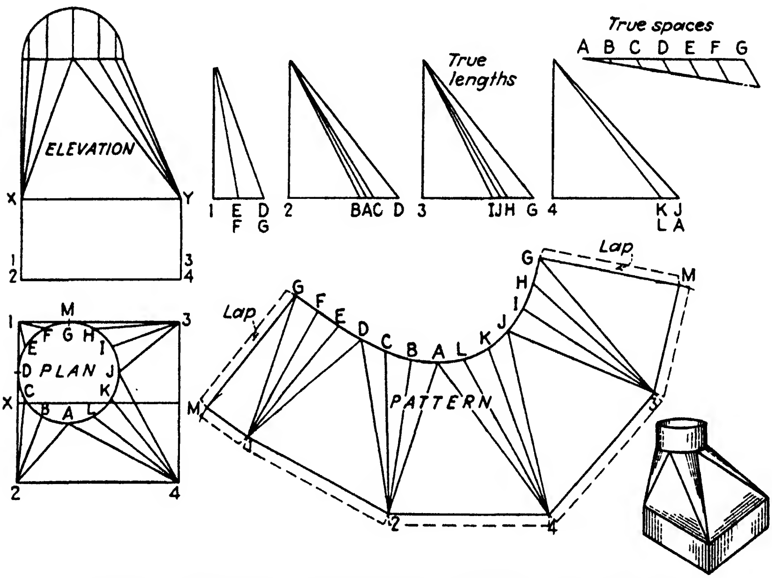


FIG. 70.—Square-to-round transition (offset two ways in plan).

In finishing the pattern shape at *GM*, it will be noticed that the plan does not show a base line, so that the vertical height is the true line at this point.

NOTE: If no base line is shown, the true length is equal to the vertical height.

Round Pipes off Center.—In this case there are two pipes with circular profiles that are off center. Diagonal lines are necessary to get from one point to another in the pattern shape.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 71

1. Draw the elevation so that one side is at right angles to the base. Divide the profiles and arrange the lines as shown, Fig. 71.

2. Draw the plan directly under the elevation, and arrange the lines to correspond with similarly numbered lines in the elevation.
3. Develop the true lengths in the two following ways:
a. By using the true elevation without the aid of the plan.
b. By using the plan without the aid of the elevation.

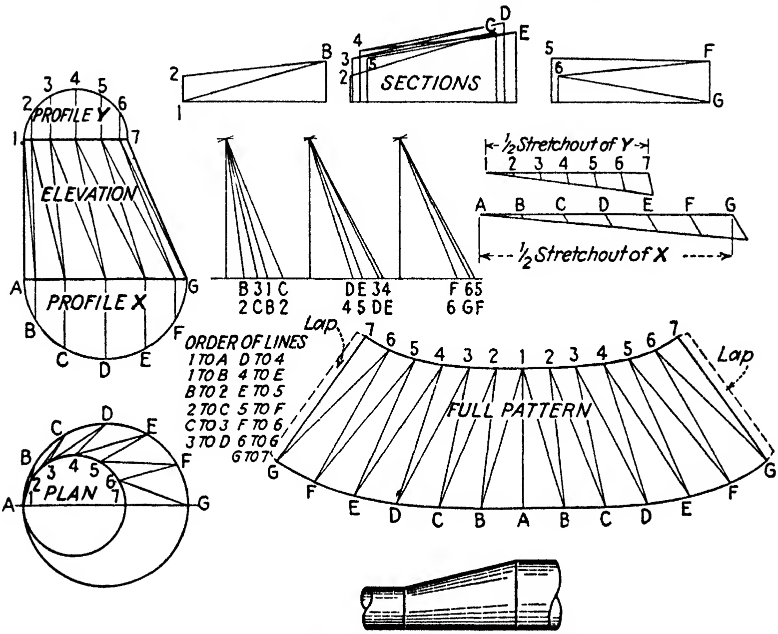


Fig. 71.—Straight-sided reduced pipe.

Note: There are now two sets of true lines, which should be of the same length provided the order of the lines in the plan is the same as the order of the lines in the elevation, as follows:

1 to *A*	3 to *D*	*F* to 6
1 to *B*	*D* to 4	6 to *G*
B to 2	4 to *E*	*G* to 7
2 to *C*	*E* to 5	
C to 3	5 to *F*	

Of course, it is understood that only one set of true lines is necessary, so it will be assumed that this fitting is developed by using the elevation without the aid of the plan.

4. Lines 1*A* and 7*G* in the elevation are on the center line. They are, therefore, true lines. Take the distance 1*A* in the elevation and erect a vertical line to start the pattern shape.

5. Taking the true length of line 1*B* from the diagram of true lengths of the sections and with 1 (in the pattern shape) as a center, draw an arc. Then, using a true space on the girth between *A* and *B* as a radius and with *A* as a center, draw another arc. The intersection of the arcs will locate point *B*.

To locate point 2 take the true length of line *B*2 from the diagram of true lengths of the sections, and with *B* as a center, draw an arc. Then, using a true space of the girth from the stretchout *Y* as a radius and with 1 in the pattern shape as a center, draw another arc. The intersecting of arcs will locate point 2.

Following the procedure, the order of lines 2*C*, *C*3, 3-*D*, etc., will complete the pattern shape. A fair curve drawn through the points in the pattern will give the correct curve of the pattern.

SUPPLEMENTARY REFERENCE SHEET 7

Rule 1.—When the halves of a symmetrical figure are symmetrical in the plan and elevation, and when the planes in the elevation are parallel, the true lines may be found by using either view, as follows:

1. By using the plan without the elevation, as only one altitude is necessary.

2. By using the elevation without the plan.

Both ways are equally good for obtaining *true surface lines.*

Rule 2.—When the halves are not symmetrical in the plan view and the planes are parallel in the elevation, the plan should be used without the aid of the elevation; only one altitude is required, and the elevation can be eliminated.

Rule 3.—When the halves are not symmetrical in the plan view and the planes are not parallel in the elevation, both views are necessary to produce true surface lines. If the altitudes in the elevation and the base lines in the plan are known, a diagram of triangles can be drawn.

Rule 4.—Symmetrical fittings having planes that are not parallel in the elevation should be developed by using the elevation without the plan.

The elevation method is known as the *simplified method.* The true surface lines are developed by taking measurements from the center to the outer edge of the profiles, forming sections or spaces.

The plan method produces true surface lines, as follows:

The base lines are taken from the plan and the altitudes from the elevation. This forms a right angle, and the including line that is drawn forms a right-angle triangle, the hypotenuse being the true length of the line required.

1. All irregular-shaped objects have different profiles, and the profiles always produce the stretchout or girth line.

2. The true surface measurements around an object can be found by developing or constructing a diagram of triangles, the hypotenuses of which will be the true lengths.

3. The true lengths accurately placed in the pattern shape between girths make it possible for the object to be laid out.

SUPPLEMENTARY REFERENCE SHEET 8

What is triangulation? The definition given in Webster's Dictionary is: "The act of triangulating; the division of a district or a country into triangular portions, as in a trigonometrical survey."

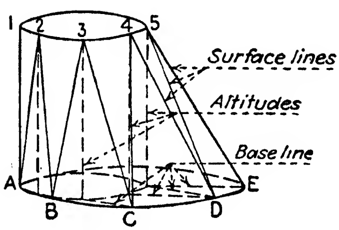


FIG. 72.

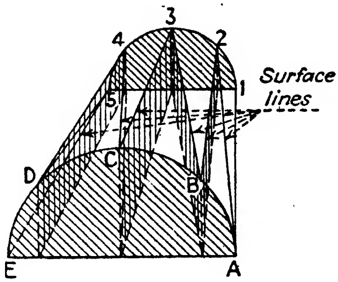


FIG. 73.

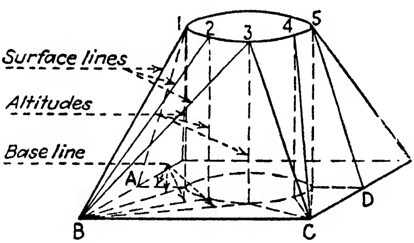


FIG. 74.

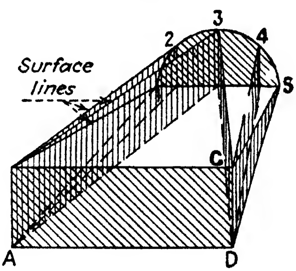


FIG. 75.

FIGS. 72 to 75.—Skeleton views showing positions of lines which form the surface and shape of irregular-shaped forms.

Some think that in pattern drafting, especially in triangulation layout work, the pattern shapes are constructed mathematically, but this is not the case. The hypotenuse of a right-angle triangle is found by squaring the base A and altitude B; and from the sum of these squares the square root is extracted. The length of the hypotenuse H is then $\sqrt{A^2 + B^2}$. If the true lengths of lines were found in this way they would not be accurate, as we have only a few "perfect" squares, such as 6, 8, and 10; 3, 4, and 5; etc. Therefore, it would be impossible to determine accurately the true lengths of lines. Even if the lines could be computed mathematically, it would be slow, tedious work.

Mathematics is applied to help in the design of many fittings where similar areas of pipes are concerned; but it cannot be successfully applied to accu-

rate development of lines. By this method lines to be developed are drawn into position in the elevation and plan views; and then a simple diagram made-up of triangles or sections will produce the desired results.

The following steps may make possible a better understanding of the term triangulation. This method may be applied to any form, and the true length of a line may be found by the construction of a simple right-angle triangle.

To develop pattern shapes by this method, the profile or section at either end of the object is drawn. This gives the edge line, or girth. The measurements around the surface of the object can be found by developing or constructing a diagram of triangles, which will show the true lengths; and in connection with the girth measurements the object can be laid out.

Supplementary Reference Sheet 9 should help in visualizing the triangulation method.

SUPPLEMENTARY REFERENCE SHEET 9

The skeleton view (Fig. 72) shows the position of the lines in a reduced round pipe straight on one side, if they were to be developed from the plan. The development of the plan is shown in Fig. 71.

Figure 73 shows the same fitting when the lines are to be developed by using the elevation without the aid of the plan.

In Figs. 74 and 75 there are skeleton views of a transition from a square to a round shape, showing the position of lines as they would appear if developed from the plan (Fig. 74, and the elevation, Fig. 75).

EXERCISES

This chapter covers the principles underlying the study of triangulation for those types of pipe fittings which have symmetrical halves and parallel planes in the elevation (see Rule 1, page 82).

For types of fittings whose halves are not the same in the plan, but whose planes are parallel in the elevation, see Rule 2, page 82.

To apply these rules, design and develop the following shapes to the dimensions given:

1. Figure 68 shows a twisted square pipe. Make a similar drawing to the following dimensions:

Size of pipe = 2-in. square.
Degrees of twist in top plane = 45 deg.
Amount of offset between the center of the top and bottom pipes = ¾ in.
Make the height of the fitting 2¾ in.

2. In Fig. 69 two methods are shown for developing true lengths of the surface lines (see Rule 1).

Draw a similar pattern to the following dimensions, without using the elevation:

Size of square pipe = 1¾ in. on a side.
Size of round pipe = 1⅛ in. in diameter.
Height of transition = 1¾ in.

3. Make a drawing exactly like Fig. 70, but instead of a $1\frac{1}{4}$ in. round pipe as shown make the round pipe $1\frac{1}{2}$ in. in diameter.

NOTE: The other dimensions are to be the same.

4. Make a straight-sided reduced pipe like Fig. 71. Change the small diameter to $1\frac{1}{2}$ in. The dimensions will then be as follows:

Small diameter	=	$1\frac{1}{2}$ in.
Large diameter	=	2 in.
Height	=	$1\frac{3}{4}$ in.

CHAPTER X

TRIANGULATION METHODS.—(*Continued*)

In work related to sheet-metal drafting there are a practically unlimited number of special cases that differ in details but are essentially similar in the fundamental principles of design and the development of surfaces. Therefore only a relatively small number of typical cases need be studied in detail to make it possible to master practically all others.

It should be understood, however, that some proficiency must be obtained before the fundamental principles and methods will be recognized in complicated cases.

The triangulation method of developing must, of course, be understood to the extent that one will recognize which principles or methods to use for the designing and developing of any pattern shape that may be met.

To accomplish these results, each chapter will treat of related groups of fittings. In Chap. IX, for example, all the figures are similar in character, because their bases lie between two parallel planes in the elevation. Therefore only one altitude is required for the lines that are taken from the plan; that is, a diagram of triangles is drawn which will have the same height. If the straight height is known there is no need to draw the elevation. All straight fittings, whether symmetrical or not, can be developed without drawing the elevation. Rules 1 and 2 (page 82) apply to this group.

In this chapter another group of fittings will be considered. Figure 76 shows the necessity of using both views for the development of a fitting. For all cases of this kind Rule 3 (page 82) applies.

Figures 77, 78, and 79 show a group of another kind of fittings. This group can be developed without the aid of the plan.

This chapter shows the familiar simplified method of developing surface lines. The developments of the lines in Figs. 77, 78, and 79 are found exactly as in the explanation for developing true lines

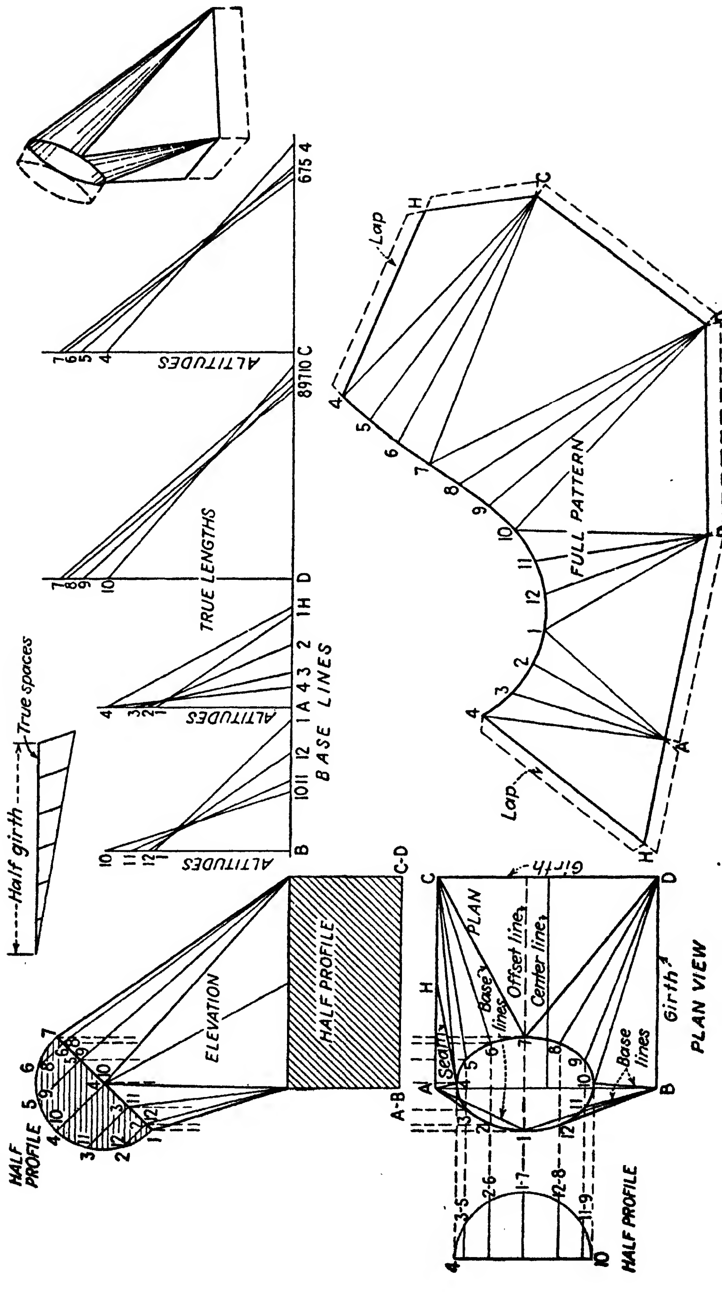


FIG. 76.—Nonsymmetrical transition piece (offset two ways in the plan view).

by sections in Chap. IX. Rule 4 (page 82) applies to all transitional elbows and offsets.

In this chapter the fittings have only three pieces. If more pieces are required, more difficult designing is involved. The method of developing lines does not change, however.

NOTE: Elbows having more than three pieces will be treated in a later chapter.

INSTRUCTIONS FOR THE DESIGNING AND DEVELOPMENT OF FIG. 76

In this case two views are necessary (see Rule 3). In all of the examples in Chap. IX the plan could have been used without reference to the elevation. In Fig. 76 there is an inclined plane in the elevation which makes the vertical depths of different lengths, whereas, in all the cases taken up in Chap. IX, the top and bottom planes were parallel and only one vertical height was required.

A plan view is required in Fig. 76 because the halves are not symmetrical. If the halves were symmetrical in the plan, however, only the elevation would be needed, and true lines would be developed by sections.

To Make a Sample for Fig. 76.—The elevation and plan views should be drawn to sample specifications as follows:

1. The round end is to be $1\frac{1}{2}$ in. in diameter and the square end $2\frac{1}{4}$ in. on each side.
2. The length of the center line in the elevation is to be 2 in., drawn at a 60-deg. angle.
3. Make the offset in the plan $\frac{3}{8}$ in.
4. The round profile in the elevation is to be drawn at right angles to the center line.

In order to obtain the shape of the round pipe in the plan, the following procedure is applicable:

1. Locate the half profile in a convenient position on the "line of offset" in the plan, as indicated by the extended line drawn through points 1 and 7.
2. Divide the profile in the usual manner; and number the division points from 1 to 12. (As only half the profile is used, there will be two numbers on each division point.) Mark the square profile *A*, *B*, *C*, and *D*.

3. From the points of intersection on the inclined plane, lines are extended down into the plan, intersecting horizontal lines drawn from similar numbers of the profile in the plan.

4. The order of lines in the plan and elevation should now read A to 1, 2, 3, and 4; C to 4, 5, 6, and 7; D to 7, 8, 9, and 10; B to 10, 11, 12, and 1. The seam is the line $4H$. All of these lines represent base lines of a right-angle triangle.

5. The base lines are now placed in position, and drawn to the various altitudes, forming a diagram of triangles the hypotenuse of which is, in each case, the true length.

6. To start the pattern shape, take the true distances in the true lengths' diagram, using $B10$ and $D10$ as radiuses; and with B and D in the pattern shape as centers, draw intersecting arcs, locating the point 10.

7. With B and D as centers in the pattern shape and with a radius equal to the distance from B to 11 and D to 9 taken from the true lengths, arcs are drawn. Then with 10 as a center and a true space of the girth as a radius, the intersection of arcs will locate points 9 and 11 in the pattern shape.

Incidentally, this pattern shape is found in exactly the same manner as Fig. 70, Chap. IX, and therefore further explanation is not necessary.

In Fig. 77 there is a *combination of the parallel and triangulation* methods of development. The end pieces of the offset are parallel forms; the middle section, being a transition, will have to be developed by triangulation.

The procedure for obtaining the true lengths of lines is called the *simplified method*. This method has already been discussed, but will be partially repeated in the successive steps.

The designing and developing of sections on the cutting planes, or miters, is the principal aim in this case. The pattern shape of the transition shows that the halves are the same, and the procedure for development is exactly like the straight-sided, round-to-round reduced pipe in Chap. IX (Fig. 71).

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 77

1. To design the offset, draw a right-angle triangle, making line $YD°$ the base and the hypotenuse $4°D°$ the center line. From the apex the legs of the offset are drawn perpendicularly

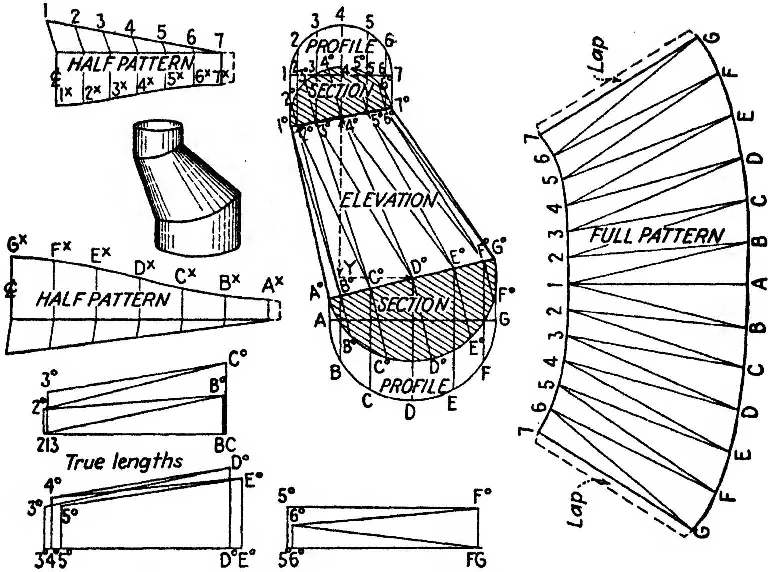


FIG. 77.—Three-piece reduced offset in round pipe.

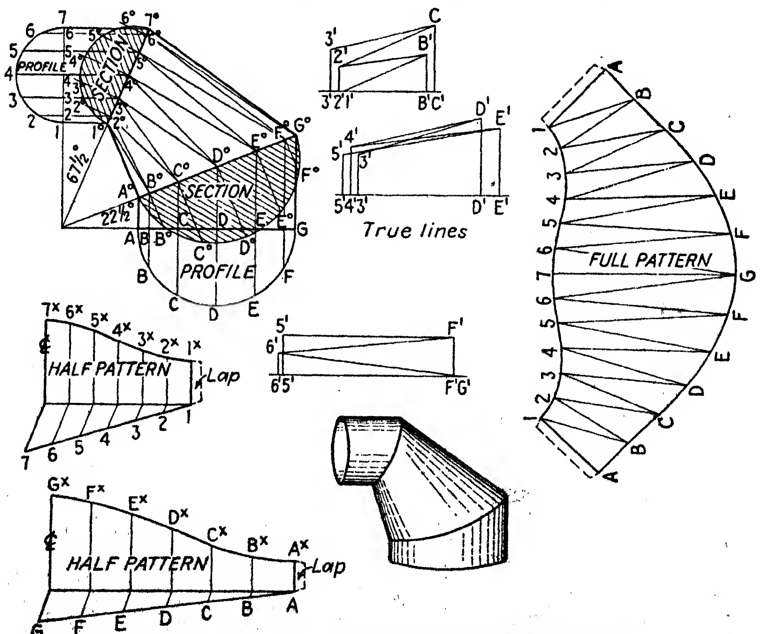


FIG. 78.—Round reducing elbow having three pieces.

from 4° and D°. The vertical legs of the angle may be drawn at any reasonable length and the profiles located as follows:

2. Place the profiles representing the diameters of the pipe at right angles to the vertical center line.

3. Bisect the angles at 4° and D°, locating the miter lines (see instructions for bisecting angles in Fig. 30, page 24).

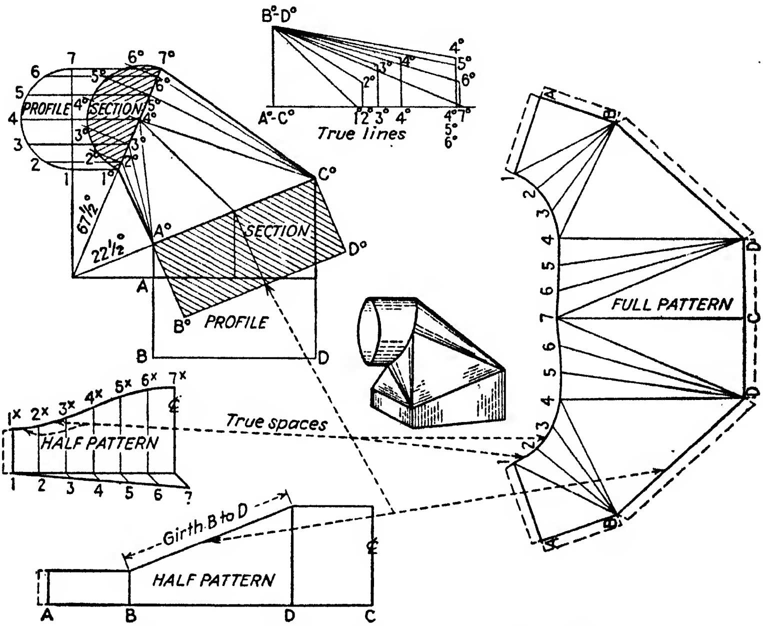


Fig. 79.—Square-to-round elbow in three pieces.

4. Divide the profiles and number the small end from 1 to 7. Mark the large end A to G. Perpendicular lines drawn from these points intersect at the junction of the small end at 1°, 2°, 3°, 4°, 5°, 6°, and 7°, and at the miter line of the large end at A°, B°, C°, D°, E°, F°, and G°.

5. A line drawn from A° to 1° and from G° to 7° completes the elevation.

6. It can be seen in this case that there is a transition, with elbow ends. The elbow patterns are developed in the usual way and should be made first.

7. Arrange the surface lines of the elevation as marked in their order as follows: A° to 1°, 1° to B°, B° to 2°, 2° to C°, C° to 3°,

3° to $D°$, $D°$ to 4°, 4° to $E°$, $E°$ to 5°, 5° to $F°$, $F°$ to 6°, 6° to $G°$, and $G°$ to 7°.

NOTE 1: Although a true section is not required for problems of this kind, it is discussed here to help the reader visualize the development of lines by *sections*. To develop the sections on the miters, lines are drawn at right angles to the intersections at the points from 1° to 7° and from $A°$ to $G°$. The distance from the center to the outer edge of the profiles is taken and placed on similar lines in the sections. Then a line drawn through the various points will complete the true half shape at the miters, which is represented by the shaded part. The shape is now more nearly an ellipse than a circle. If these shaded portions were bent at right angles, the section would look like the skeleton in Fig. 83.

NOTE 2: The distance from the center to the outer edge of the profile equals the distances of the sections. Therefore there is no need of developing sections at the miters, as 4-4 of the profile equals 4°-4° of the section, and 3-3 equals 3°-3°, etc. On miter lines of any three-pieced transitional elbows the sections can be eliminated, as the heights for the true lines can be taken from the end profile.

NOTE 3: Further proof that the sections are not needed is found in the fact that the circumference of the edge line for the irregular-shaped pattern must equal the girth of the irregular-edge line of the elbow pattern. If the elbow ends are developed first, therefore, the spaces can be taken from the irregular curve. If the girth of the sections is checked, it will be found that their spaces equal those of the elbow ends on the curved part.

NOTE 4: The sections have been developed on the miters for Figs. 77, 78, and 79, so that the reader will be able to visualize more clearly the development of the surface lines. Figure 83 should be of special aid in picturing the edge lines or girths, and should also assist one in visualizing the various sections when in position. The term developed by sections is therefore used in this connection. This term is referred to as the *simplified method*, and is exactly what the name implies, since the plan view is not needed. By elimination of the plan in such problems as this chapter treats, much time is saved.

NOTE 5: Figures 6 and 7 (Chap. I) show a developed section on a roof line. This, incidentally, is the same as developing a true shape on the miter line of a three-pieced transitional elbow.

INSTRUCTIONS FOR THE DEVELOPMENT OF PATTERN SHAPE FOR MIDDLE PIECE OF OFFSET

1. As the distance from 1° to $A°$ in the elevation is on the center line, this distance is a true line. This line is convenient for starting the pattern shape.

2. Draw an arc using point 1 as a center in the pattern and the distance from 1° to $B°$ of the true lengths as a radius. Using the true girth or space between A and B, as marked A^xB^x of the elbow

pattern, as a radius and with A as a center, draw another arc. Point B will be located in the pattern at the intersection of the arcs.

3. With B in the pattern shape as a center and the distance from B° to 2° of the true lengths as a radius, draw an arc. Another arc with a radius equal to the space in the elbow pattern marked 1^x2^x, with the point 1 in the pattern shape as a center, will locate point 2 at the intersection of the two arcs.

4. Continue in this manner until all the true lines are placed in position.

INSTRUCTIONS FOR THE DESIGNING OF ANY THREE-PIECED 90-DEG. TRANSFORMING ELBOW

1. Draw the center line and locate the miters, which should be drawn at 22½ and 67½ deg. respectively.
2. Place the profiles in position.
3. Draw parallel lines from the profiles to the miters.
4. The connecting lines of the elbow ends form the shape of the transformation piece, which is usually square-to-round, oval-to-round, or round-to-round.

In Figs. 78 and 79 are shown a round-to-round reducing elbow and a square-to-round elbow.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIGS. 78 AND 79

See notes in Supplementary Reference Sheet 10 of this chapter on designing elbows in three pieces.

The pattern shapes for the middle sections of the elbows are developed like those of Figs. 69 and 71 of Chap. IX.

NOTE: In all three-piece transitional elbows or offsets, the middle-piece girths must equal those of the end pieces. This is indicated by means of arrows in Fig. 79.

SUPPLEMENTARY REFERENCE SHEET 10

The figures in this supplementary reference sheet show how the miter lines are found in any three-pieced *offset* or *elbow* (see Figs. 80 and 81).

In Chaps. I and II methods for bisecting angles and locating miters in elbows and offsets were fully discussed. They need no further mention at this point, with the exception that in all transitional elbows and offsets a center line must be drawn first. The miters are then located and the profiles of the ends placed in position. As the ends are always parallel forms, points of the profile are extended to intersect the miter line. Their shapes are developed like those of any parallel form.

The middle piece of any three-pieced offset or elbow usually takes the form of some straight irregular figure, such as a round-to-round reduced pipe or a square-to-round transition, etc.

These straight fittings have been discussed in Chap. IX, so there should be little difficulty with any of the problems of this chapter, as the methods of

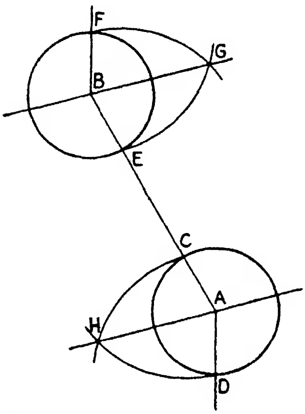


Fig. 80.—Center line for a three-piece offset elbow.

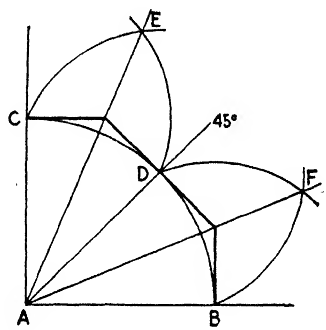


Fig. 81.—Center line for a three-piece 90-deg. elbow.

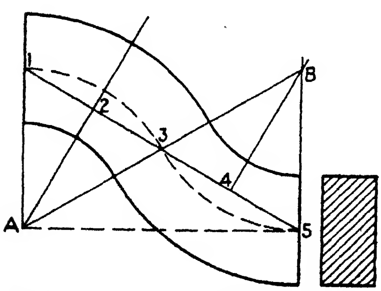


Fig. 82.—Method for designing offsets in square pipe.

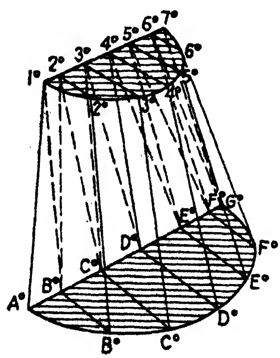


Fig. 83.—Skeleton of a transition piece showing elements of the surface.

procedure are exactly the same for developing the transition for the elbows and offset. The only difference is that elbow ends are added to the design.

In Fig. 82 there is another example of designing an offset. Although this design has no direct bearing on any of the problems discussed in this chapter, it should prove to be of special help to those who are interested in *duct construction.*

Assuming that an offset is required in a rectangular duct, let $A5$ and 1 represent the amount of offset. Divide the line 1 and 5 into four equal parts as indicated at 2, 3, and 4.

Square a line from the hypotenuse at 4 and 2, locating B and A. Then B and A are the centers from which the arcs are drawn. This will give the cheek pattern. The patterns for the throat and back are straight pieces (see page 180).

Figure 83 shows the skeleton of the middle piece of the offset for Fig. 77. A close examination will show the surface lines in position, and will also reveal a piece of metal, cut to the shape of the elevation for the middle piece, with the sections added, and bent at 90 deg. By assuming that the piece is rolled out from end to end, and then by carefully tracing the path it takes on a piece of paper, the results will be the half-pattern shape for the transition part of the offset.

EXERCISES

The problems in this chapter present both the plan and elevation views when they are required to produce true surface lines, and also cases for which only the elevation need be drawn.

Figure 77 shows a three-pieced offset whose large diameter is 2 in. and whose small diameter is 1¼ in. Make the pattern shape of the offset, assuming that these same diameters are required.

The offset between the center lines $D°Y$ is to be 1¼ in., and the vertical depth ($Y4°$) is to measure 2¼ in.

Instead of developing the true lines by sections, as shown in Fig. 77, show a plan and develop the lines by making a diagram of triangles. The lines in the plan will be base lines, and the varying heights in the elevation will be the altitudes. With these two measurements of the various elements, a diagram of true lines can be formed.

CHAPTER XI

METHODS OF DESIGN

Four different methods of sheet-metal design are explained in this chapter. In two of these, the simplified method of developing lines is used to advantage. In Chaps. IX and X all the methods of developing lines were discussed. For the remaining chapters designing will be of major importance.

Figure 84 shows an irregular tee intersecting a round pipe. Although round profiles are used, the intersecting pipe could be of any desired shape and at any angle, without changing the method of designing or developing.

Figure 85 presents a simplified method of developing a Y branch without using or showing a vertical section. This same problem will be given in Chap. XII, where a section on a vertical junction will be shown.

Figure 86 shows a Y branch developed with the aid of a plan drawing. This case could have been developed without the aid of the plan, as the halves are symmetrical. If the planes were inclined like the sketch and the plan method were used for developing lines, varying altitudes could be obtained.

Figure 87 treats a hopper whose plan shows that it is symmetrical. Because of the twist, however, it is best to use both views.

INSTRUCTIONS FOR THE DESIGNING AND DEVELOPMENT OF FIG. 84

1. Draw the main pipe, dividing its profile as marked by points A, B, C, D, E, F, and G. Extend parallel lines from these points to the full length of the pipe.

2. At any convenient distance from the center line of the main pipe, draw the center line of the tee. From this point erect the center line of the return elbow vertically and parallel to the main pipe.

3. Bisect the return angle, thus locating the miter line. Next place the profile of the tee in a suitable position. Then

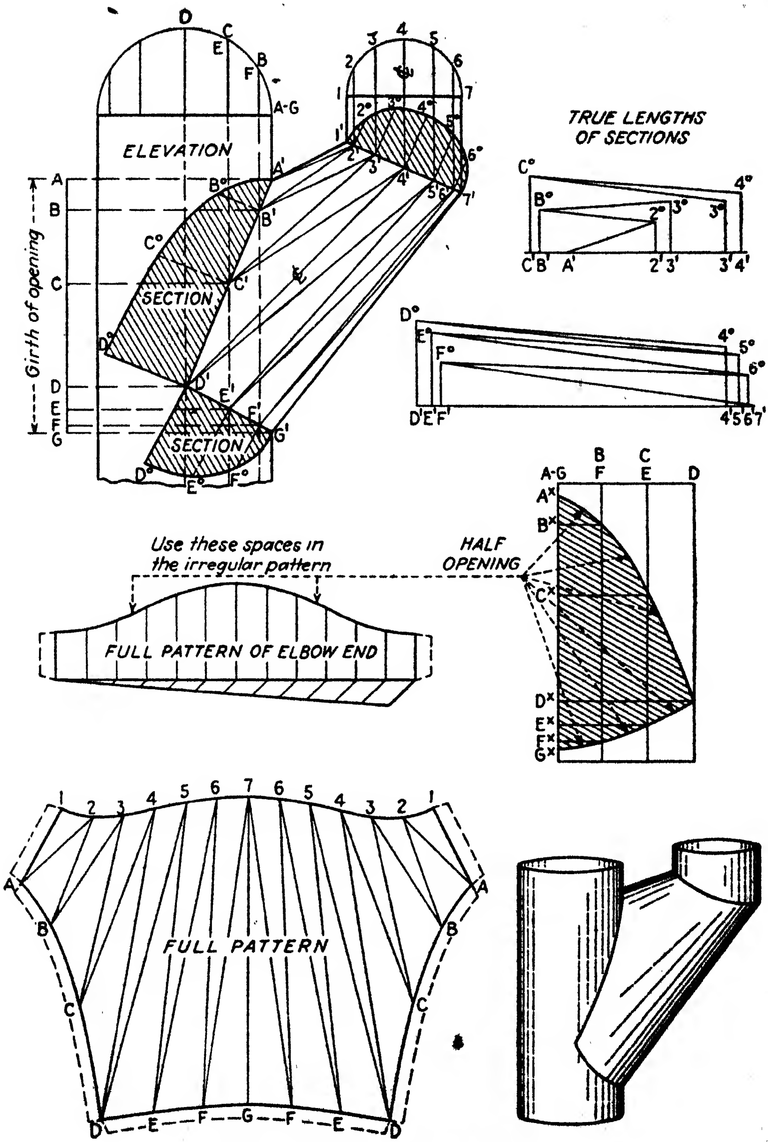


Fig. 84.—Transforming tee joint.

divide the profile into six equal parts, and from each of the division points as marked 1 to 7, draw lines to the miter line, intersecting it at points 1′ to 7′.

4. The lines marked 1′A′ and 7′G′ are drawn conveniently, and the amount of flare given them controls the size of opening in the main pipe.

5. Draw lines from D′ to G′ and from D′ to A′, which will locate the cutting plane of the tee. Where the vertical lines in the main pipe penetrate the cutting planes, points B′, C′, E′, and F′ will be located.

6. Arrange the order of lines in the elevation for their development as follows: 1′A′, A′2′, 2′B′, B′3′, 3′C′, C′4′, 4′D′, D′5′, 5′E′, E′6′, 6′F′, F′7′.

7. To develop the true sections of the miters, draw lines at right angles from points B′, C′, D′, E′, and F′. The distances in the profile of the main pipe from the center to the outside curve at D, C, and B are placed at B′B°, C′C°, D′D°, E′E°, and F′F°. A fair curve drawn through these points completes the half sections.

8. To develop the half section of the elbow miter, draw lines at right angles from points 2′, 3′, 4′, 5′, and 6′. The distances from the center to the outer edge of their respective numbers in the profile are placed in position, locating 2′-2°, 3′-3°, 4′-4°, 5′-5°, and 6′-6°.

9. The procedure for developing the true lines is the same as given in previous chapters. Lines of the elevation representing the surface elements are taken out and placed horizontally, as the order of lines is given in step 6. The vertical distances are those of the section or profile, and the including line that is drawn is the true length.

10. To develop the half shape of the opening in the main pipe, the vertical distances between A′ and B′, C′ and D′, E′ and F′, and G′ in the elevation are taken and placed on a vertical line, as indicated by the center line of the opening at A^x, B^x, C^x, D^x, E^x, F^x, and G^x.

11. At right angles to the center line of the opening, place the girth or spaces of the circumference of the profile at the main pipe, as marked at AG, BF, CE, and D. Lines drawn down at right angles from these points will intersect similar points drawn horizontally from the vertical center line. A fair curve drawn

through these points will complete the half shape of the opening.

12. Start the pattern shape by using the true line $7'G'$ of the elevation.

NOTE: The lines $7'G'$ and $A'1'$ of the elevation are true lines, as they are on the center.

13. The procedure for the pattern shape is the same as for any of the cases previously given. A summary may be given as follows:

a. Center edge lines of all symmetrical fittings are true in the elevation; all others must be developed.

b. Lines should be numbered or lettered and placed in position in the pattern shape as their placement is shown in the elevation.

c. The true girths or circumferences for irregular shapes should be computed for all fittings having parallel planes. See Fig. 71. If the fittings have elbow ends, the girths may be taken from the true section at the miter or around the irregularly curved part of the elbow pattern.

d. In the case shown in Fig. 84, the girth of the transition may be taken around the opening (whose spaces should equal those of the section) and around the irregular curve of the elbow end, as indicated by arrows.

A Y branch developed by sections (without a section developed on the vertical junction) is shown in Fig. 85. The branch is developed as though there were no junction at all. Deductions are made for the cutout or shaded portion of the pattern shape after the full pattern is developed.

INSTRUCTIONS FOR THE DESIGNING AND DEVELOPMENT OF FIG. 85

1. Draw the center line of the branch at 60 deg., and at right angles to this center line draw the profile of the small pipe.

2. Draw the profile of the large pipe, dividing the profiles and marking them as indicated, using the letters A to G and the numbers 1 to 7.

3. A line then drawn from 1 to A and another from 7 to G completes the elevation for one branch. A vertical line drawn

from D of the profile represents the joining line of the branches.

4. Arrange the lines in their order 1 to A, 1 to B, B to 2, 2 to C, C to 3, 3 to D, D to 4, 4 to E, E to 5, 5 to F, F to 6, 6 to G, and G to 7. Mark the penetrating lines of the junction with the letters L, M, N, O, and P.

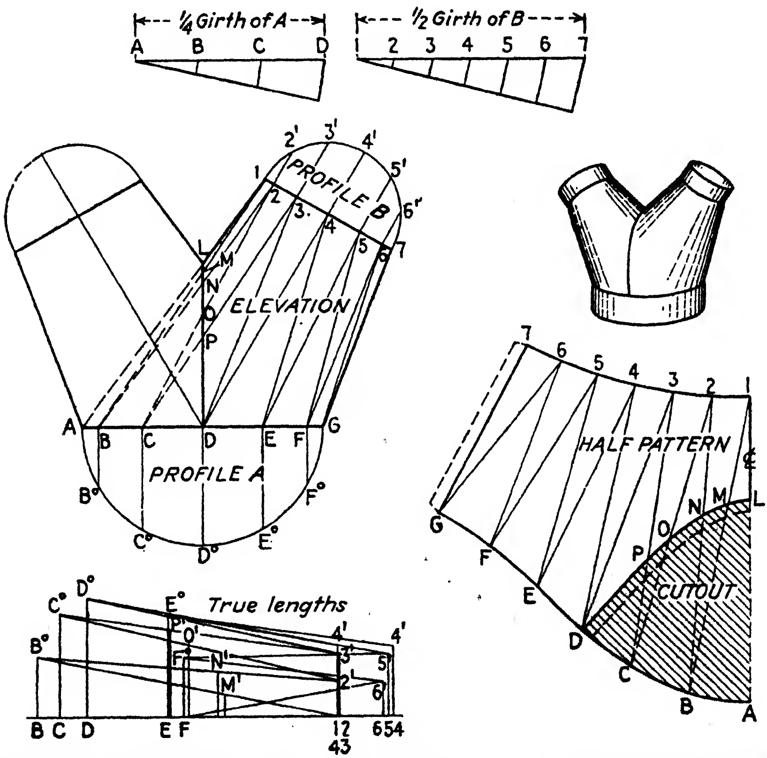


FIG. 85.—Simplified method for Y branches when round necks and center angles are the same for both branches.

5. Develop the true lines by sections and place them in the pattern shape in the usual way. The cutout at L, M, N, O, and P is found as follows:

Since the distance from 1 to L in the elevation is the length of a true line, this line ($1L$) on the line $1A$ in the pattern shape locates point L.

To locate M, take the distance BM in the elevation and place it on the horizontal line $B1$ of the sections. Erect a vertical

height, intersecting the line from B to 1 at M'. With the true slant $B°M'$ as a radius and B in the pattern shape as a center, draw the radius, locating M.

To locate N, take the distance BN on line $B2$ of the elevation, and lay off this distance on the horizontal line of the section marked $B2$ of the diagram. Erect a line intersecting $B2$ at N'. With $B°N'$ of the true length as a radius and B in the pattern shape as a center, draw the radius, thus locating N. Points O and P are found in exactly the same way.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 86

This figure shows another way for developing lines with the aid of the plan. This method could be applied also to Fig. 85.

The center line is to be drawn at 60 deg. Designing of the Y branch is done in exactly the same way as in Fig. 85.

The lines are developed with the aid of the plan. If the planes were inclined like the sketch (Fig. 86*a*) they would have varying altitudes, whereas in this case there is only one altitude. In either case, the lines may be developed as follows:

1. With the aid of the plan—draw both views.
2. By using the elevation without the plan, as in Fig. 85.

This figure shows a simple square-to-round pattern of which the halves are symmetrical, but the top plane is off the center line. In this case, the half pattern of the transition is to be developed, and points L', L, M, N, O, and X are to be located. A line drawn through these points will give the cutout for the vertical miter.

This case is exactly like Fig. 85. It needs no explanation other than the statement that the lengths for the cutout at points at L, M, N, O, and X are found by drawing horizontal lines from L, and M, N, and O of the junction in the elevation, which intersect similarly lettered lines in the true-line diagram. For example, point L intersects the true length $C1$; point M intersects the true line $C2$; point N intersects the true line $C3$; and point O intersects the true line $C4$.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 87

1. This is an example of a twisted hopper with a square end. It has a half twist, as shown in the plan at A, B, and C. Draw

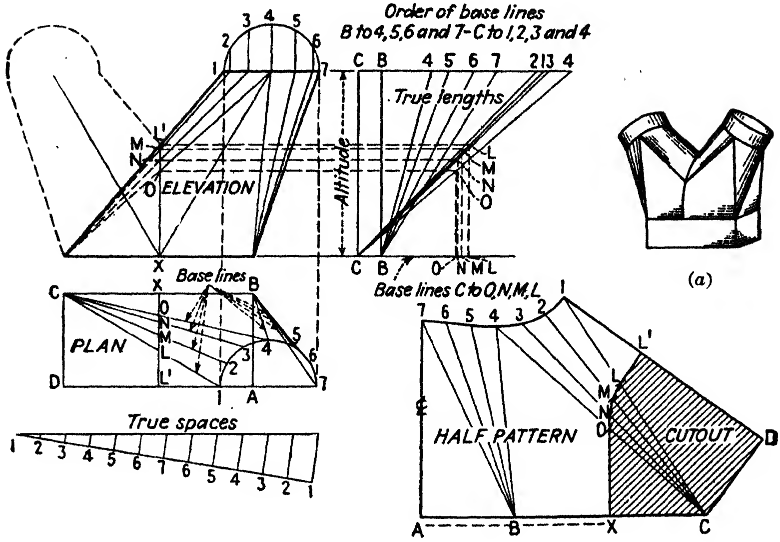


Fig. 86.—Two way Y branch developed with aid of the plan.

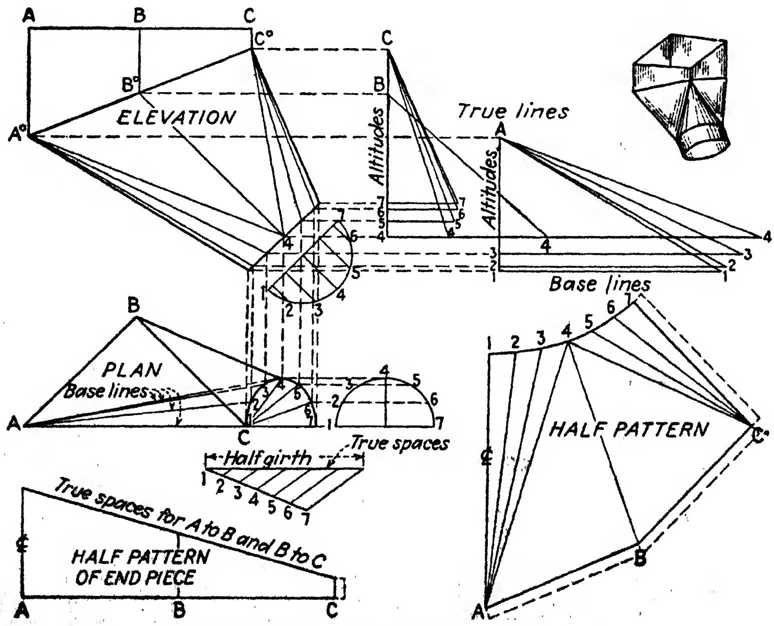


Fig. 87.—Square-to-round twisted hopper.

lines from A, B, and C to intersect a horizontal plane in the elevation as at A, B, and C.

2. Draw the center line of the hopper, marking it with the letters, B, B°, and 4. The center line B, B°, and 4 makes an angle of 45 deg.

3. At right angles to the center line at point 4, draw a line equal in length to the diameter of the round end.

4. Draw the profile in the elevation; number the divisions 1 to 7; and complete the elevation by locating the miter line (bisect the angle). Place lines in position to read, C° to 4, 5, 6, and 7; and also A° to 4, 3, 2, and 1.

5. Arrange the lines in the plan to correspond to those in the elevation.

6. Develop the true lines by arranging the various altitudes and bases.

7. Develop a true girth for spaces in the pattern shape of the round end.

8. The true girth at the junction of the square end of the pattern is to be taken from the elbow end. The procedure for the pattern is the same as for a square-to-round transition.

EXERCISES

1. Assuming that the intersecting pipe is square instead of round in Fig. 84, make a drawing whereby the square pipe will measure 1⅛ in. on a side, and will intersect a 1¾-in. round pipe at an angle of 45 deg.

2. Develop a similar pattern shape for Fig. 86, using the following dimensions:

Diameter of round end	=	1½ in.
Size of square end (full profile)	=	2¾ by 2 in.
Perpendicular height	=	2¾ in.
Offset between centers	=	1½ in.

CHAPTER XII

HORIZONTAL Y BRANCHES

This chapter shows additional methods for the development of horizontal Y branches. In Chap. XI a simplified method was given, whereby no vertical section was required. Now in Figs. 88 and 89 the lines are developed by the aid of a section on the joining line. Also in Figs. 90, 91, and 92 there are examples of Y branches of such simplicity in design and development that they can be used to advantage in warm-air piping. This method of design eliminates a vertical junction and is the cheapest way to make a Y fitting.

This chapter concludes the study of horizontal Y branches. If any other shapes are encountered, the same methods of designing and developing can be used.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 88

As the round necks are to be 1¼ in., the large pipe size will be 1¾ in., as calculated in Supplementary Reference Sheet 11.

1. Draw the center line of the branches at 60 deg. Make the center line 2¾ in. long.
2. Draw the half profiles of the small ends at right angles to the center line, and number each division from 1 to 7.
3. Draw the profile of the large end, and mark each division of the quarter *A*, *B*, *C*, and *D*.
4. Erect a vertical line representing the junction line, the height for which is marked *K*. Draw a line from *K* to 1, and from *D* to 7.

NOTE: The point *K* is located at pleasure.

5. To draw the shape of the section through the vertical junction at $A°K$, use any reasonable radius. This radius of the small pipe size will usually be satisfactory. Then, with this radius, a circle may be made.
6. Draw a line from A^x tangent to the circle, which completes the section. This is the half shape that the Y will now have at $A°K$.

7. Extend the line of the radius to H°, and divide the curve H° to K into three equal parts.

NOTE: Three parts will suffice for any Y branch.

8. Mark the division as indicated in the figure thus, A^x, H°, I°, J°, and K; and from H°, I°, and J°, draw horizontal lines to the center line, intersecting KA° at H, I, and J.

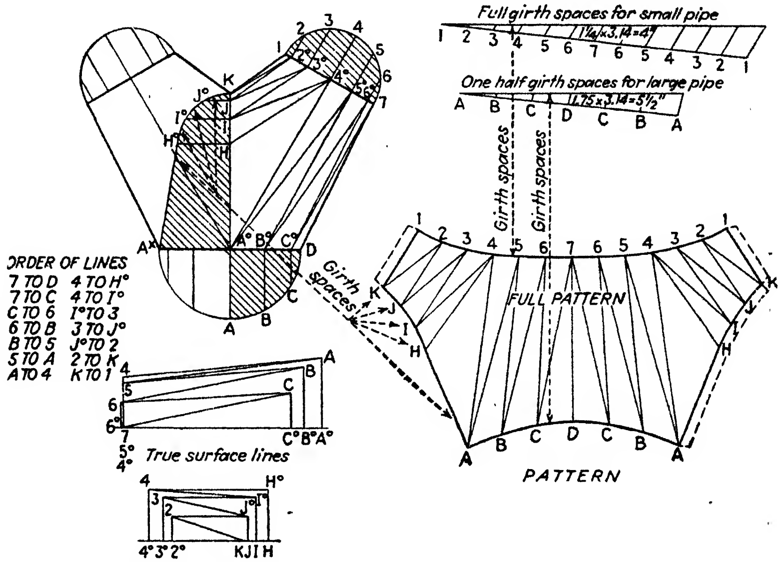


FIG. 88.—Two-pronged fork having a vertical section.

9. Arrange the surface lines to be developed in their order: 1 to K, K to 2°, 2° to J, J to 3°, 3° to I, I to 4°, 4° to H, 4° to A°, A° to 5°, 5° to B°, B° to 6°, 6° to C°, C° to 7, 7 to D.

10. Develop the lines by sections. For example: To develop the line $2^\circ J$ the space $(2^\circ J)$ is placed on a horizontal line. From the extreme points of the line, erect lines equal in length to 2°-2 of the profile and JJ° of the section. The including line drawn from J° to 2 is the true length of the line.

NOTE: The method for developing lines by sections is the same for all fittings where the halves are symmetrical. Each line is developed as in step 10 and as found in its respective order as in step 9.

Continue in this way until all the lines have been developed. Figure 95 gives a pictorial sketch of the sections when in posi-

tion. It shows the vertical half section and the half profiles of the ends when bent at 90 deg. with the surface lines drawn in position. It should enable the reader to visualize each section for the development of every line.

11. To start the pattern, locate line 7*D* of the elevation (which is a true line) in the pattern shape.

12. With point 7 in the pattern shape as a center and 7*C* of the true length as a radius, draw an arc; and with a true space of the big-end girth, draw another arc. The intersecting arcs will locate point *C* in the pattern.

13. To locate point 6 in the pattern, use the true length *C*6 as a radius, and with *C* in the pattern shape as a center, draw an arc. Then, with a true space of the small-end girth, draw another arc. The intersecting arcs will locate point 6.

NOTE: Taking the lines in their respective sequence, as given in the order of lines, each is placed in position as in steps 12 and 13. The girth of the vertical junction is taken from the curved part of the section between A° and H°, H° and I°, I° and J°, and also J° and K, whereas the girth spaces for the circular ends are computed. Arrows indicate where spaces are taken and placed.

Two-way Y Branch Having Square Necks

Figure 89 shows a two-way Y fitting, having square-elbow ends connected to a round pipe of equal area. In this case, the square pipe is 1¼ in. on a side and the round pipe is 2 in. in diameter. (See Supplementary Reference Sheet 11 on proportioning pipe sizes, page 112.)

The necks of the Y are 2 in. between their centers. The angle is to be drawn at 60 deg.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 89

1. The length of the center line is to be 2 in., drawn at a 60-deg. angle.

2. Draw vertical lines as at *XY*, making these lines of any reasonable length.

3. The angle $XY4^{\circ}$ is then bisected to locate the miter line.

4. Place the half profile of the square end in position, and mark as indicated the points *C*, *B*, *A*, and *D*. Extend *CB* and *AD* to the miter line, thus locating D° and C°.

5. Draw lines at right angles to the miter; and place the distance from the center to the outer edge of the profile *CB* and *DA* in the half section on the miter line, locating lines $D^\circ A^\circ$ and $C^\circ B^\circ$.

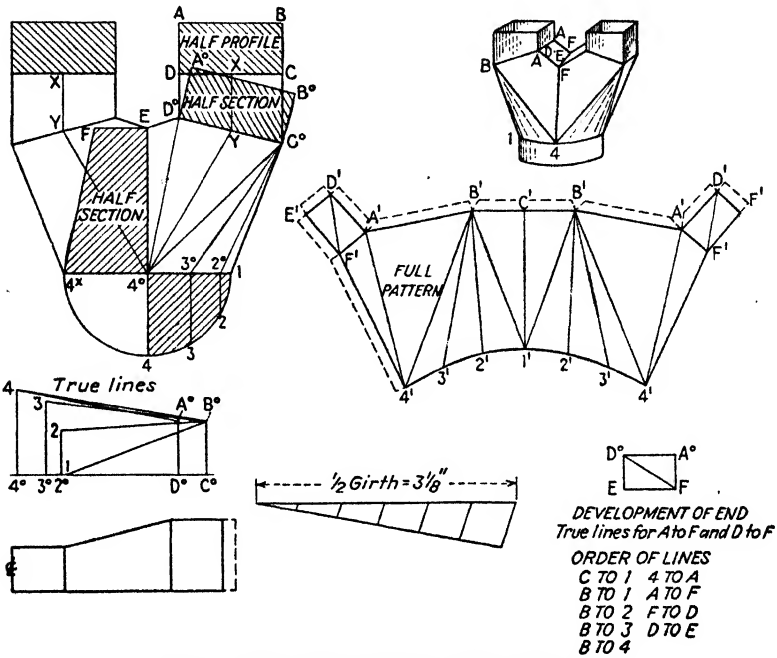


FIG. 89.—Two-way Y branch with square necks.

6. Place the diameter of the round end in position, and divide and number the profile in the usual way.

7. Erect the vertical junction from 4° to *E*, and draw lines from 1 to C° and from *E* to D°, which completes the elevation.

NOTE: The point *E* is located at pleasure.

8. Draw the lines to be developed in their proper positions, as the order of lines indicates.

NOTE: The vertical section in the Y fitting is to be made square. However, the section could be rounded as in Fig. 88. Both ways are equally good.

9. Make the distance from *E* to *F* equal to half the width of the profile. A line drawn from *F* to 4^x completes the section, that is, the true given shape on line $4^\circ E$.

10. Develop the true lengths of the lines by sections as previously instructed in Fig. 88, and arrange them in a diagram of true lines.

11. Start the pattern shape at $C'1'$, which is equal to the length of the line in the elevation $C°1$. ($C°1$, being on center, is a true line.) A horizontal line is drawn at right angles to the line $C'1'$; and the distance of the flat side ($C°B°$) of the section is placed on the line in the pattern, locating $B'B'$.

12. With B' in the pattern shape as a center and with $B°2$ of the true lengths as a radius, draw an arc. With $1'$ as a center, draw another arc equal to the true space of the round girth. At the intersection of the arcs $2'$ is located. $3'$ and $4'$ are located in the same way.

13. To locate A' in the pattern, draw an arc using $4'$ as a center and the true length $4A°$ as a radius. Then, with B' as a center, draw another arc with a radius equal to the distance in the half section marked $B°$ to A^a in the elevation. At the intersection of the arcs A' is located.

14. Using the true length of the line on the vertical junction 4^xF in the half section (4^xF is true) and with $4'$ in the pattern shape as a center, draw an arc. Then with the true space $A°F$ as a radius and A' in the pattern shape as a center, draw another arc. The intersection of the arcs will locate point F'.

NOTE: To develop the flat part to complete the pattern, draw a diagram equal to lines in the elevation between $ED°$, $D°A°$, and EF as indicated. Draw a diagonal line from F to $D°$. Transfer this diagram into the pattern shape, locating $A'D'$, $F'D'$, $D'E'$, and $F'E'$, which completes the pattern.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 90

This case shows a three-way horizontal branch. The designing and locating of junctions and the section through $D°H$ is similar to Fig. 89. Point H is located casually as was point K in Fig. 88. As the miter is inclined, D^x is located by drawing a line at right angles to the line $D°H$. Then a line drawn from D^x tangent to the back of the arc completes the section of the miter line. The length of the radius to use for a section in any Y branch should not be greater than the diameter of the profile. In this case the same radius as that of the profiles was used. If the profiles are of different diameters, the radius used for the section should average their diameters.

NOTE: If one of the branches were of a different angle another section would have to be drawn. The profiles may be square, round, or oval. The procedure for developing the true lengths and the pattern shape, however, remains the same as in Figs. 88 and 89.

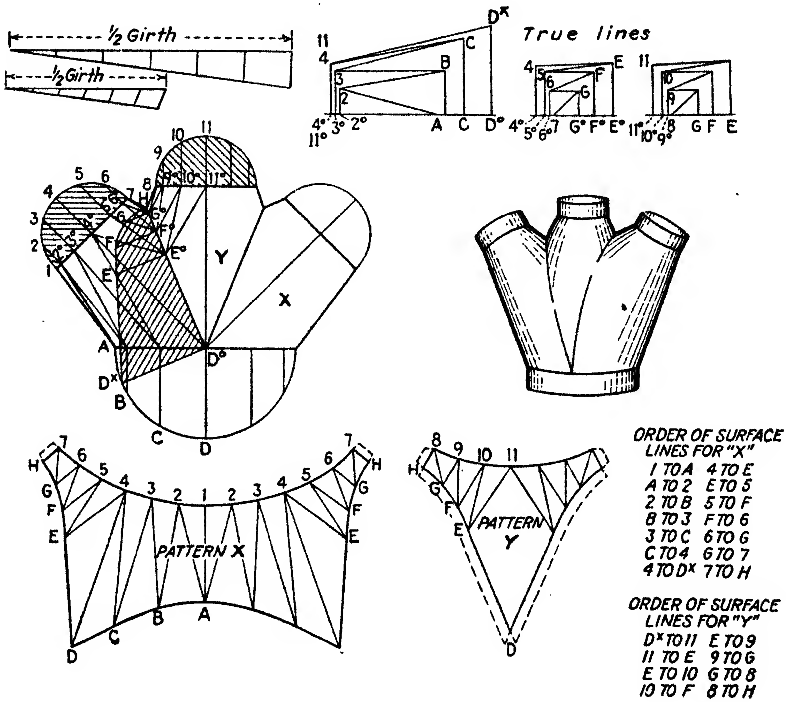


FIG. 90.—Three-way horizontal Y branch.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 91

This type of Y branch may be made with several outlets of different angles, without the use of a joining line or a junction as in Figs. 88 and 89.

The area of the large pipe should equal the combined areas of the small pipes. The profiles may be made square, rectangular, or round. The procedure for designing and developing the true lines is so similar to Figs. 88–89 that no further explanation is necessary. Compute the equivalent areas, as instructed in Supplementary Reference Sheet 11.

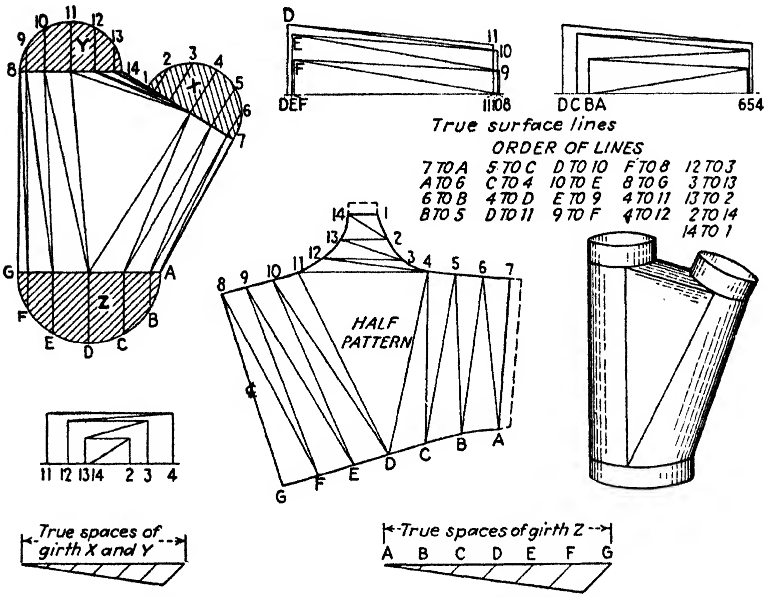


FIG. 91.—Simplified development of a Y branch.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 92

In the Y branch shown in Fig. 92, the short method of developing the true lines and the pattern shape could have been used. This case only serves to show that the plan can be used in conjunction with the elevation on all types of fittings; but as the halves are symmetrical the plan could be eliminated, and the simplified method could be used to advantage as in Fig. 91.

When the plan is used, all its lines are base lines of some right-angle triangle. In this case there are parallel planes in one branch, and only one altitude is required. However, in the other branch the planes are not parallel to the horizontal base, and there are consequently varying altitudes.

The inclined plane is developed in the plan view by taking a quarter of the profile as marked with the letters *H* to *N*. Horizontal lines drawn from these positions will intersect lines drawn down from the inclined plane of the elevation into the plan view, locating points *H*, *I*, *J*, *K*, *L*, *M*, and *N*.

The profiles of the parallel planes are circles in the plan, the divisions and lines of which should correspond to the positions of lines in the elevation, or to the order of lines given.

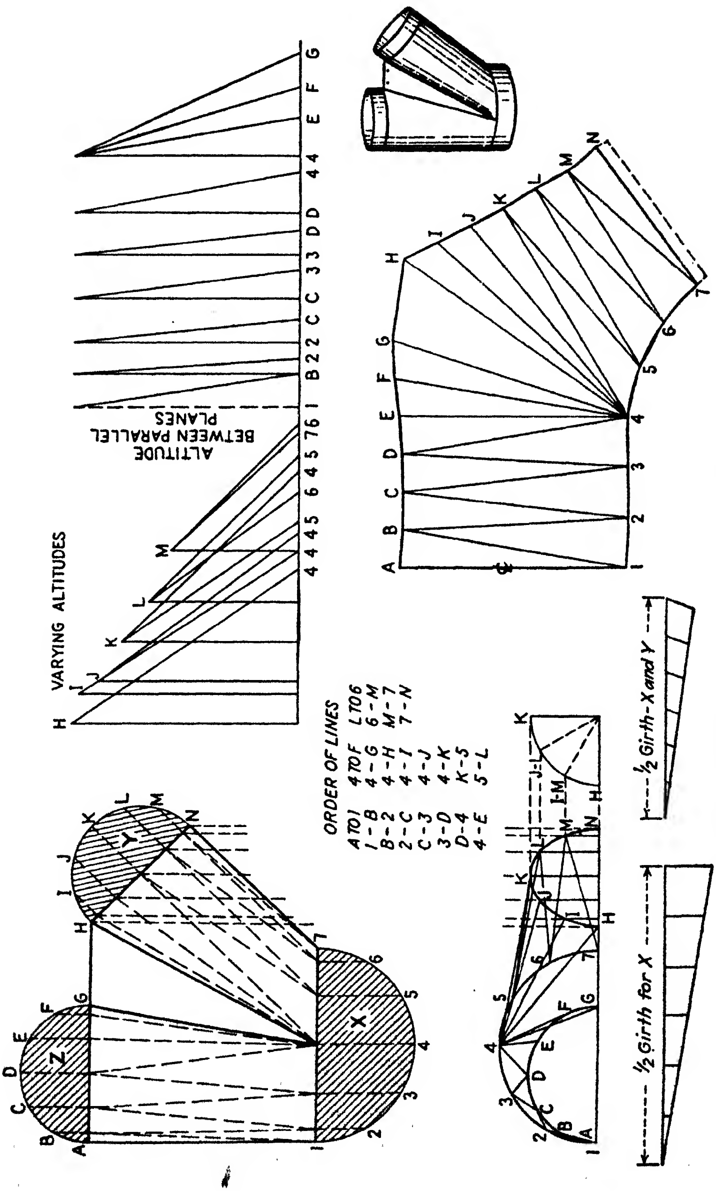


FIG. 92.—Simplified development of a Y fitting (use of plan).

The profiles may be made either square or round. Compute the similar areas as explained in Supplementary Reference Sheets 11 and 12.

SUPPLEMENTARY REFERENCE SHEET 11

Figures 93, 94, and 95 show the position of the lines in a two-way Y branch, in which the order of lines is the same as in Fig. 88, namely: 1 to k, k to 2, 2 to j, j to 3, 3 to i, i to 4, 4 to h, 4 to a, a to 5, 5 to b, b to 6, 6 to c, c to 7, and 7 to d.

Figure 93 shows the pictorial view as the lines would appear on the surface.

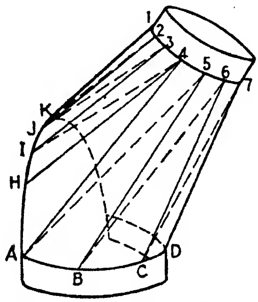


FIG. 93.—Visual aids in triangulation.

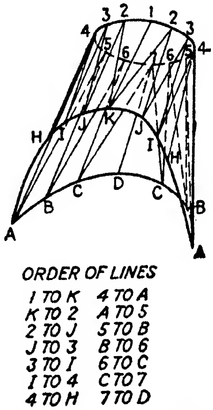


FIG. 94.—Visual aids in triangulation.

Figure 94 shows another view as the surface lines would appear entirely around the branch.

Figure 95 shows the position of the lines in a pictorial section. The view is a visual aid for developing lines by sections.

Figure 96 represents a steel square and shows a practical method for determining pipe sizes when the areas are to be equal.

Example. A Y branch is required of which the branches are to be 4 in. and 5 in. in diameter. The large diameter, in order to serve the branches, would be the diagonal of 4 in. and 5 in. on the steel square. As the even inches would have to be calculated, the diagonal or

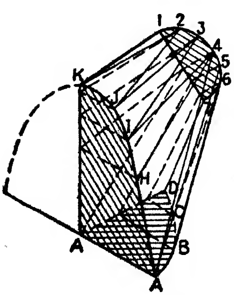


FIG. 95.—Visual aids in triangulation.

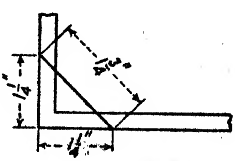


FIG. 96.—Proportioning pipe sizes on the steel square. (See Reference Sheets 11 and 12.)

hypothenuse would be nearly 6½ in. To check this mathematically, the following formula is given:

$$\begin{aligned}\text{Hypotenuse} &= \sqrt{\text{small dia.}^2 + \text{large dia.}^2}\\ &= \sqrt{4^2 + 5^2}\\ &= \sqrt{16 + 25}\end{aligned}$$

$$\begin{array}{l} \sqrt{41.00}\,\underline{|6.40}, \text{ nearly } 6\tfrac{1}{2} \text{ in.}\\ \quad 36 \\ \underline{124}|\overline{500} \\ \quad\;\; \underline{496} \end{array}$$

By computing the areas the corresponding results would be as follows:

$$\begin{aligned} 5^2 \times 0.7854 &= 18.73\\ 4^2 \times 0.7854 &= \underline{12.56}\\ \text{Total areas} &= 31.29 \end{aligned}$$

(5-in. and 4-in. pipes)

$$\begin{aligned}\text{The area of } 6\tfrac{1}{2}\text{-in. pipe} &= 6.5^2 \times 0.7854\\ &= 33.19 \text{ sq. in.}\end{aligned}$$

The above example shows that the area of a 6½-in. pipe is nearly equal to the combined areas of a 4-in. and 5-in. pipe. Square pipe sizes may be computed on the steel square in the same way as round pipes.

Figure 89 shows a two-way Y branch of which the necks are square instead of round.

The round-pipe size in this case would be calculated in one of two ways.

First Method. 1. By consulting a table of areas.

2. By using the formula $D = \sqrt{\text{area} \times 1.2732}$.

Example: Assuming that we have two square pipes, measuring 2 in. on a side

$$\begin{aligned}\text{Then } 2 \times 2 &= 4 \text{ sq. in. (area of one neck)}\\ \text{and } 2 \times 4 &= 8 \text{ sq. in. (area of two necks)}\end{aligned}$$

The nearest diameter of a round pipe having an area of 8 sq. in. is about 3³⁄₁₆ in.

Second Method. The combined area of the square pipes is 8 sq. in., therefore

$$\begin{aligned} D &= \sqrt{\text{area} \times 1.2732}\\ \text{Substituting} &= \sqrt{8 \times 1.2732}\\ &= \sqrt{10.1856}\\ &= 3.190 \text{ about } 3\tfrac{3}{16} \text{ in.}\end{aligned}$$

SUPPLEMENTARY REFERENCE SHEET 12

Figure 90 shows a three-way horizontal Y branch with branch pipe sizes all of which are 1¼ in. The diagonal on the steel square for the large pipe size is measured as follows:

The diagonal of 1¼ in. on the steel square is 1¾ in., and the diagonal of 1¾ in. and 1¼ in. is nearly 2¼ in. Therefore, 2¼ in. would be the pipe size to compensate for the area of all of its branches.

To prove this the following equation may be used:

$$\begin{aligned} D &= \sqrt{1\tfrac{1}{4}^2 + 1\tfrac{1}{4}^2 + 1\tfrac{1}{4}^2} \\ &= \sqrt{4.68} \\ &= 2.16 = \text{about } 2\tfrac{11}{64} \text{ in. } (2\tfrac{1}{4} \text{ in. will suffice}) \end{aligned}$$

Assuming that a three-way Y branch has 2-in. *square* necks and that a *square* pipe is to serve them:

Then by the same formula,

$$\begin{aligned} \text{Side of the square} &= \sqrt{2^2 + 2^2 + 2^2} \\ &= \sqrt{1{,}200}\ \underline{|3.46} \end{aligned}$$

$$\begin{array}{r|r} & 9 \\ \hline 64 & 300 \\ & 256 \\ \hline 686 & 4{,}400 \\ & \underline{4{,}116} \end{array}$$

The square-pipe size will be $3\frac{1}{2}$ in. on a side.

If the large pipe were a rectangle $2\frac{1}{2}$ in. long, the width would be

$$\begin{aligned} 2^2 + 2^2 + 2^2 &= 12 \text{ sq. in.} = \text{area of three necks.} \\ 12 \div 2\tfrac{1}{2} &= \text{nearly 5 in.} \end{aligned}$$

That is, a $2\frac{1}{2}$- by 5-in. pipe will compensate for the area of the three 2-in. square pipes.

Any pipe size may be computed in Y branches in the following three ways:

1. $H = \sqrt{A^2 + B^2}$
2. By using a steel square.
3. By consulting a table of areas.

SUPPLEMENTARY REFERENCE SHEET 13

The elevation on pages 115 and 116 shows the designs of eight different Y branches. If the Y branches were of different profiles it would not affect their design. Neither would it affect the developing of lines, as they are all symmetrical fittings and are developed in exactly the same ways as Figs. 88 and 89.

In Figs. 97, 98, 99, and 100, the sections on the vertical and inclined miters are rounded. That is, a radius equal to the small-diameter pipe size is drawn as indicated. With x as a center and xa as a radius, a quarter circle is drawn; then a line from C, drawn tangent to the back of the arc (as indicated at bc) completes the section.

If it is desired to make the section larger through xb, a larger radius may be used. The section of a vertical or inclined miter may be square as in Fig. 89.

Point a is established as may be convenient in all horizontal Y branches that have junctions.

In designing any Y branch, the center line or skeleton is drawn first. That is to say, the center lines are drawn and the profiles placed in position. Point a is located conveniently, and lines drawn to a and c complete the elevation. If a Y branch is encountered as in Fig. 98, the miters must be

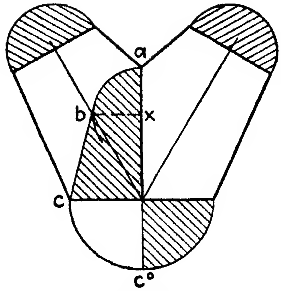


FIG. 97.—First type of horizontal Y branch.

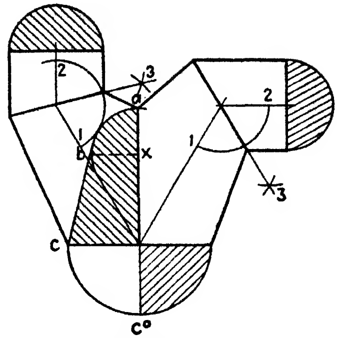


FIG. 98.—Second type of horizontal Y branch.

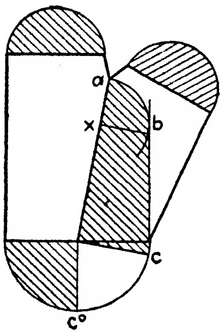


FIG. 99.—Third type of horizontal Y branch.

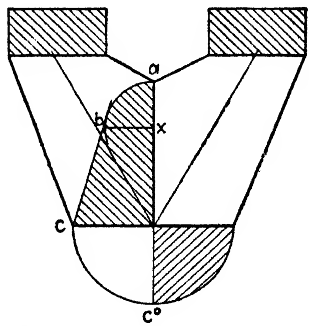


FIG. 100.—Fourth type of horizontal Y branch.

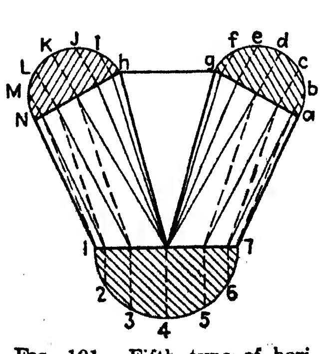


FIG. 101.—Fifth type of horizontal Y branch.

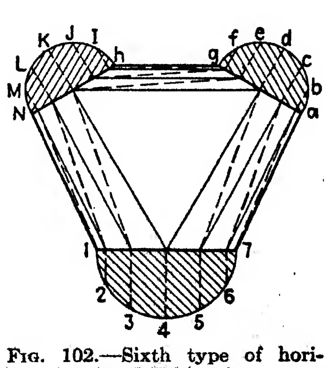


FIG. 102.—Sixth type of horizontal Y branch.

located for the elbow ends. First the center lines are drawn, the profiles being placed in position. The angles are bisected, producing a correct miter. Point *a* is placed at pleasure; and lines drawn parallel from the profiles of the elbow ends to the miter line, then to *a* and *c*, complete the elevation.

Figures 101, 102, 103, and 104 show Y branches without a junction. That is, the whole pattern shape could be developed in one piece without joints on the vertical or inclined miters. This type of Y connection may have any number of branches. The figures show the order of the lines as they should be placed and numbered. Any system of numbering and arranging of lines

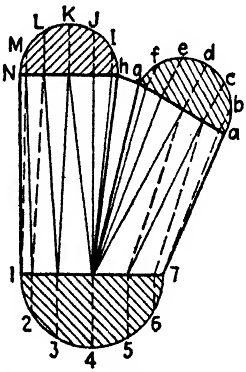


FIG. 103.—Seventh type of horizontal Y branch.

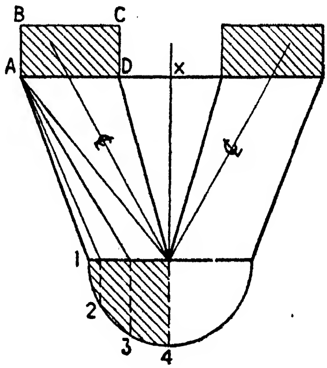


FIG. 104.—Eighth type of horizontal Y branch.

will suffice, provided the order of drawing lines is properly understood and the arrangement is reasonable. It must be remembered that whatever the arrangement of lines is to be, the lines must be developed and arranged in the pattern shape as they are arranged in the elevation or plan views.

EXERCISES

Usually the large-sized pipe of a Y fitting is made to compensate for the area of its branches.

1. If the large diameter in Fig. 97 is 2 in., what is its small diameter?

2. Figure 100 shows a Y branch with square necks. If the large diameter is 2½ in., find the size of two square pipes of equal area whose combined areas would equal that of the 2½-in. diameter pipe.

3. If the large diameter of Fig. 90 is 2½ in. and its branches are of equal area, and the combined areas equal the area of a 2½-in. pipe, compute the diameters of the small-branch pipes.

Design a three-way horizontal Y to the above dimensions as computed, showing the true elements of the surface and its pattern shapes.

CHAPTER XIII

CLUSTERED Y BRANCHES

This chapter deals with Y branches in clustered forms. Figures 105 and 107 show the development of a three-way cluster, in which the sum of the areas of the branch pipes is equal in area to the large round pipe. On the other hand, Fig. 106 has four branches all of which are attached to one pipe of equal area. In Fig. 107, the branch pipes are square, and in Fig. 105 the branches and the large end are round. Figure 108 shows a simplified method of making a Y branch without a developed section.

Supplementary reference sheets are not required in this chapter, as the method of developing the lines and pattern shapes is similar to the developments in Chap. XII.

The four examples given in this chapter are principally intended to illustrate the various methods of designing and locating true sections for three- and four-way clusters. In previous chapters the methods of developing true surface lines and true girths have been thoroughly discussed; and in this chapter only the designing of the three- and four-way pronged forks will be considered.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 105

1. Draw the angle of the Y branch from a horizontal plane as at $E4'$. At right angles to $E4'$, locate the diameter 1-7 as marked. Divide the profile, numbering each division, and draw lines to the inclined plane as indicated at points 6′, 5′, 4′, 3′, and 2′.

2. Establish point A at pleasure on a vertical line drawn from point E; and with a radius equal to the profile, X, draw the arc of a circle, which will be the curve for the true section.

3. Locate the diameter of the large end of the pipe as marked at E° to H; and from E° draw a line tangent to the back of the arc. Extend the radius line to point D, and divide the curved line DA into three equal parts, as marked D, C, B, and A.

4. Draw the plan of the large pipe, which is a circle, and divide it into three parts, starting from point E', one-third of which will

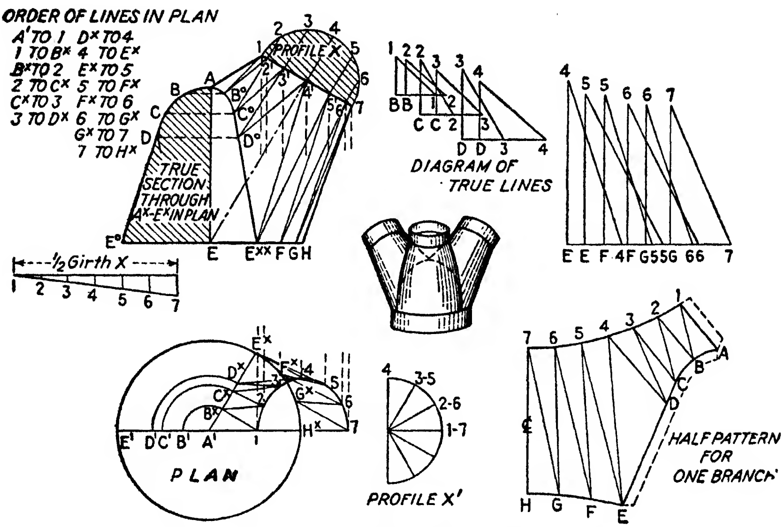


Fig. 105.—Three-way branch in cluster form.

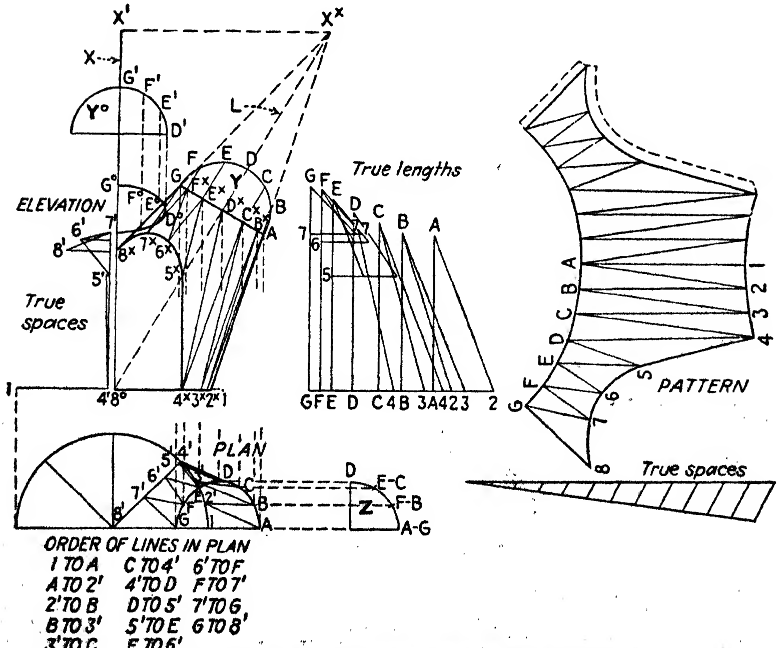


Fig. 106.—Four-pronged clustered Y branch.

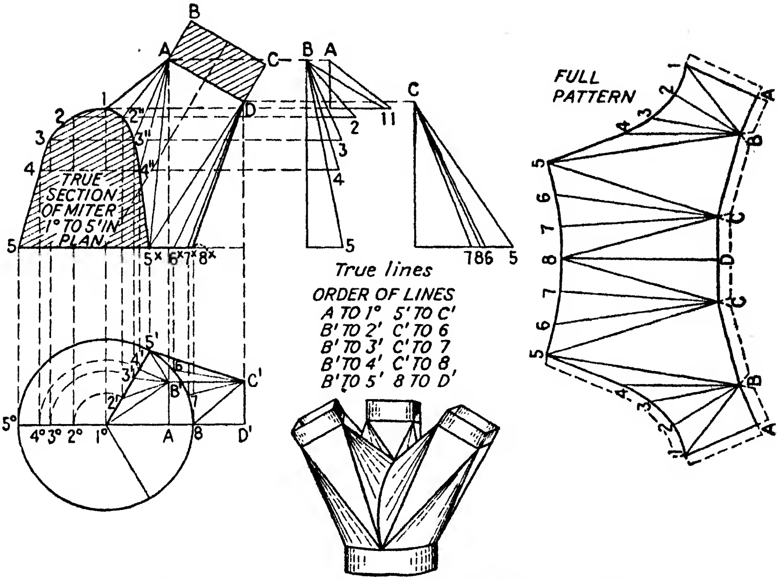


FIG. 107.—Three-way cluster having square necks.

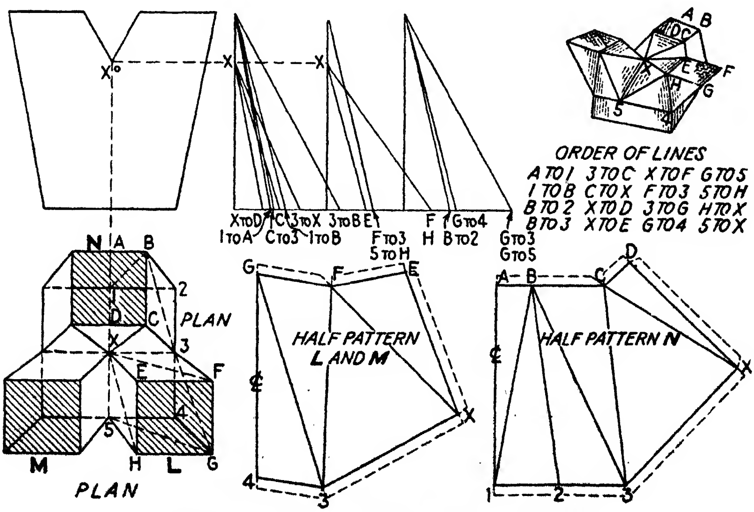


FIG. 108.—Three-way cluster in square pipe.

locate E^x. Draw a line from E^x to the center A'. This line represents the joining line of which the true section in the elevation is its true shape.

5. Extend the lines from the section A, B, C, D, and $E°$ into the plan, locating points E', D', C', B'. With A' as a center, draw arcs from these positions, locating the points of the miter line at B^x, C^x, D^x, and E^x.

6. Extend lines from these points to the elevation, intersecting the similarly numbered lines drawn horizontally from D, C, and B, thus locating $B°$, $C°$, and $D°$.

NOTE: A line drawn from A to $B°$, $C°$, $D°$, and E^{xx} establishes the true position of the miter line in the elevation.

7. Extend lines into the plan from the points 1, 2′, 3′, 4′, 5′, 6′, and 7 of the elevation. Lines drawn horizontally from the profile X' will intersect similar numbers, which will develop the true shape in the plan of the inclined plane (1-7) of the elevation.

8. Arrange the lines in both the plan and the elevation according to the order of the lines as given.

9. Arrange the base lines and altitudes to form a diagram of true lengths. Proceed in the usual way with the pattern shape.

NOTE: The girth of the pattern between the points E, D, C, B, and A is taken from the true section in the elevation just as the points are spaced. The girth of the pattern between H, G, F, and E is taken from the spaces in the plan between H^x, G^x, F^x, and E^x.

The fitting shown in Fig. 106 has four round pipes which branch out from a larger round pipe. The area of the larger pipe compensates for the area of its four branches, as equal areas must be maintained.

The branches could be square or oval without affecting the designing or developing of the lines.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 106

1. Erect a perpendicular line at right angles to the horizontal base line as indicated at $8°X$.

2. Draw the center line $8°L$ at 60 deg. to the horizontal, assuming that all the branches are to be at that angle.

NOTE: The branches could all be at different angles and could be developed from the same vertical section, and the profiles could be of different shapes.

3. In this case, at right angles to the center line, draw the profile Y as shown. Divide and number as indicated.

4. Mark off one-half the diameter on each side of the center 8° to locate point 1. From this latter point draw a line through A, locating the apex X^x.

5. From X^x draw a line through G, locating the point 8^x.

6. As the cluster is to have four branches, the miter lines will be at 45 deg. in the plan. Locate these miters in the proper position.

7. Draw a horizontal line from the apex X^x to the vertical center, thus locating X'.

8. To locate the ellipse or front view of the inclined end of the pipe, place the profile Y on the vertical center line, as indicated at Y°.

9. Lines drawn vertically downward from points of the profile Y° will intersect the lines drawn horizontally from the points G, F^x, E^x, D^x, C^x, B^x, and A, locating G°, F°, E°, and D°.

10. Lines drawn from the apex X' through F°, E°, and D° will intersect lines drawn from the apex X^x through F^x, E^x, and D^x, thus locating 7^x, 6^x, and 5^x.

11. The miter line of the plan locates point $4'$ in the plan; and a perpendicular line from this point $4'$ drawn to the base of the elevation will locate 4^x.

12. A fair curve through points 8^x, 7^x, 6^x, and 5^x, and a straight line from 4^x drawn tangent to the back of the arc at 5^x will complete the curved miter line in the elevation.

13. Draw lines downward from 7^x, 6^x, 5^x into the plan to intersect the miter line at $7'$, $6'$, and $5'$. Divide the circle in the plan between $4'$ and 1 into three equal parts, as indicated at points $3'$ and $2'$.

14. Erect perpendicular lines from $3'$ and $2'$ of the plan to the base line of the elevation, locating points 3^x and 2^x.

15. The shape of the inclined plane in the elevation must be shown in the plan. Lines drawn from points G, F^x, E^x, D^x, C^x, B^x, and A into the plan will intersect similarly numbered lines drawn horizontally from the profile Z, thus completing the shape of the inclined plane of the elevation G to A in the plan.

16. Arrange the lines in the elevation and plan according to the order of the lines as given.

17. Make a diagram having true lines equal to the base lines of the plan and the varying altitudes of the elevation, the hypotenuses of which will be the true lengths desired.

18. The true girth between points 8^x, 7^x, 6^x, 5^x, and 4^x is next developed. Use the spaces on the miter line in the plan between lines 8′-7′, 7′-6′, 6′-5′, 5′-4′ as the base lines. Then, by using the altitudes between the same numbers in the elevation, the true spaces needed in the pattern shape will be provided.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 107

This case is designed exactly like Fig. 105. The only difference is that the Y branch has square necks, whereas in Fig. 105 the necks were round.

To compute the equivalent areas, or to find the diameter of the round end, we have:

$$D = \sqrt{\text{area} \times 1.2732}$$
$$D = \sqrt{3 \times 1.2732}$$
$$D = \text{approximately } 2 \text{ in.}$$

Arrange the lines as the order of lines is given.

The case illustrated by Fig. 108 shows three square pipes, branching from a square base. The arrangement of the branches could be designed at different angles and at a different offset. If desired, the branches could be made with a twist. The development of the branches remains the same whether two, three, or four branches are required.

To simplify the explanation, the branches in the plan have been made symmetrical to the base of the large square pipe.

As equal areas are necessary, the large pipe will be made to have equal areas of the three-branch pipes. In this case assume that three 1-in. square pipes are used. Therefore, the square root of combined areas (3 sq. in.) will equal the side of the square.

$$\begin{array}{r|l}
 & \sqrt{3 \text{ sq. in.}}\ \big|\ \underline{1.73} \\
 & 1 \\
\underline{27} & \overline{200} \\
 & 189 \\
\underline{343} & \overline{1{,}100} \\
 & \underline{1{,}029}
\end{array}$$

The side of the large square pipe will be $1\frac{3}{4}$ in. (approximately).

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 108

1. Draw the base of the square pipe in the plan, and arrange the position of the three square pipes.

2. As the halves are symmetrical, only half of the plan is needed. Number the base as follows: 1, 2, 3, 4, and 5. Mark one small branch *A*, *B*, *C*, and *D*, the other *E*, *F*, *G*, and *H*.

3. Arrange the base lines of the plan in the order of the lines as given.

4. Draw the elevation, thus establishing $X°$.

5. In this case two altitudes are to be considered. Develop the lines to the order of the lines as given, and arrange them in the same order as in the pattern shape.

EXERCISES

1. Using dimensions similar to those taken for Fig. 105, calculate similar areas for a three-way Y branch, with round necks.

2. The sheet-metal fitting shown in Fig. 106 has four round pipes. Each is 1¼ in. in diameter. These are the branches of a pipe 2½ in. in diameter. The area of the latter round pipe must compensate for the area of the four branches. Make a similar design with branches, each of which is 1½ in. in diameter.

3. As equal areas are necessary, the branch pipes of a sheet-metal fitting must be made to have a total area equal to that of the three branch pipes.

Assuming your own dimensions, develop the patterns for a *Y* branch similar to Fig. 108.

CHAPTER XIV

PARALLEL-LINE METHODS (ADVANCED)

This chapter introduces advanced problems adapted for the parallel-line method. Two duct fittings are discussed. Figure 109 shows a tapering compound-curved elbow. Figure 110 shows a similarly designed simple elbow, having but one 90-deg. turn, which is developed with *gore pieces*.

In the tapering compound-curved type, the elbow "turns" 90 deg. in both the plan and the elevation views, and the profiles are of different sizes. If the profiles were square, the elbow would be a plain compound-curved type. Figure 109 shows that the curves of the patterns are tapered, whereas, if the profiles were square, the curves would be parallel. The same method for designing and developing prevails whether the elbow has a *compound* curve or whether it has a *tapering compound* curve.

Figure 111 introduces a method for designing a hopper where all the flare is on one side and the back is straight. Three views are necessary for the development of its lines. The side view is designed by right-angle projection. If the hopper were of another shape, the method of designing or developing would not be changed.

A hopper of this kind is commonly used in conjunction with package-filling machinery, or for a similar purpose.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 109

1. The throat radius for both the elevation and the plan is to be drawn from the centers of right angles at X and Y. The ends of the elbow are indicated by the shaded portions.

2. Locate the width of the shaded portion of the plan in the elevation, as indicated at point 10. The width of the shaded portion of the elevation projected into the plan will locate h.

3. Lay off the distance $X10$ on the line $1°$-1, which will locate the center from which the arc of the back is drawn. In this case the radius intersects the same point of the throat radius.

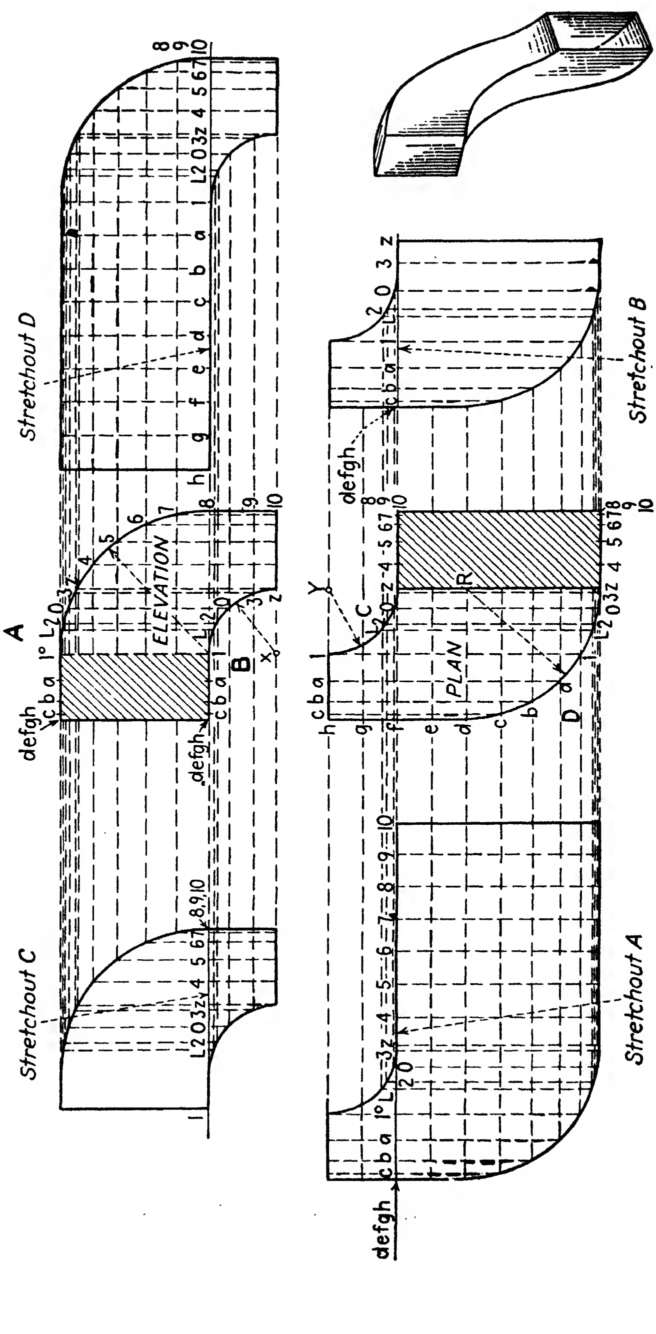


FIG. 109.—Tapering compound-curved elbow in rectangular pipe.

4. With point 1 as a center and 1-1° as a radius, draw the arc of the back. A straight line projected from point 10 to the back of the arc completes the elevation.

5. To locate R, take the distance from Y to h and lay it off on the line $Z°Z$. With R as a center and $RZ°$ as a radius, draw the arc of the back. A line drawn from h tangent to the arc of the back completes the plan.

6. Divide the arc of the back in the elevation, and number the divisions from 1° to 10. Lines drawn downward from these divisions through the curve of the throats B and C and to the arc of the back D locate spaces of the girth.

7. As Z does not come on an equal division, it must be located in the elevation.

8. As the space between points 1 and 2 in the throat at C makes them far apart, locate another space as indicated at L, and then locate L in all the curves.

9. Divide the distance of the plan between points 1 and h, locating thus points a, b, c, d, e, f, and g. Then extend these positions to the elevation.

NOTE: Any number of divisions may be made. They do not necessarily have to be equal spaces. But the divisions must be taken into account in the stretchout exactly as they are located in the elevation and plan views.

10. By taking the girths and arranging them as the arrows indicate, lines are drawn vertically from established points and from similarly numbered points in the plan and elevation. Horizontal lines are then drawn, intersecting the vertical lines of the same numbers, which complete the pattern shapes.

NOTE: The stretchouts are reversed. Those of the plan are located in the elevation as at C and D, and those of the elevation as at A and B.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 110

1. The side view of the elbow is designed exactly like Fig. 109. The gore line P is drawn by erecting lines from points of the throat, whose lines will intersect horizontal lines drawn from points of the back, forming the curved line of the gore.

2. Divide the arc of the back and number each division as indicated from 1° to 6′ (six spaces). Divide the arc of the throat and number each division as indicated from 1 to 6 (five spaces).

3. To make allowances for a connection of another pipe, a straight part is added, as marked 1° to *O*.

4. Draw the front view of the elbow.

5. A horizontal line drawn from point 6 in the side view will intersect a vertical line drawn from 6^x, establishing point 6 in the front view.

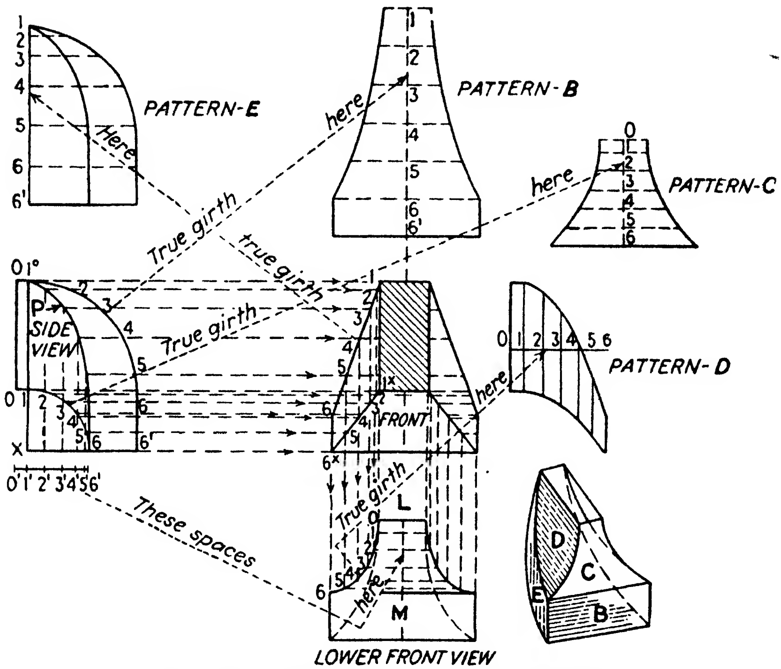


FIG. 110.—Rectangular elbow with gore pieces.

6. A line from 6 to 1 and another from 6^x to 1^x complete the front view above the ground line.

7. Extend horizontal lines from points of the throat and back in the side view to the miters of the front view.

8. To draw the lower front view, take the spaces marked 0′, 1′, 2′, 3′, 4′, 5′, and 6′ in the side elevation and place them on the center line *LM*.

9. Horizontal lines from these positions will intersect similarly numbered lines drawn downward from the upper front

view, which locate the true girth to be used for the pattern marked *D*.

10. To obtain the pattern shapes of *B* and *C*, obtain the girths from the side views as the arrows indicate. Pattern *B* may be obtained by projecting lines from similarly numbered points of the upper front view, which will intersect horizontal lines of the pattern.

11. As pattern *C* is not placed directly under the front view, the widths from the center to the outer edge of the front view are transferred to the girth of the pattern.

12. Patterns *E* and *D* are found by projection. Place the girths in position as the arrows indicate and project the lines as would be done in any parallel-line development.

STRAIGHT-SIDED HOPPER

Figure 111 introduces another method for designing. As the back of the hopper is straight and the front is flared, three views are necessary in order to locate point X' of the plan.

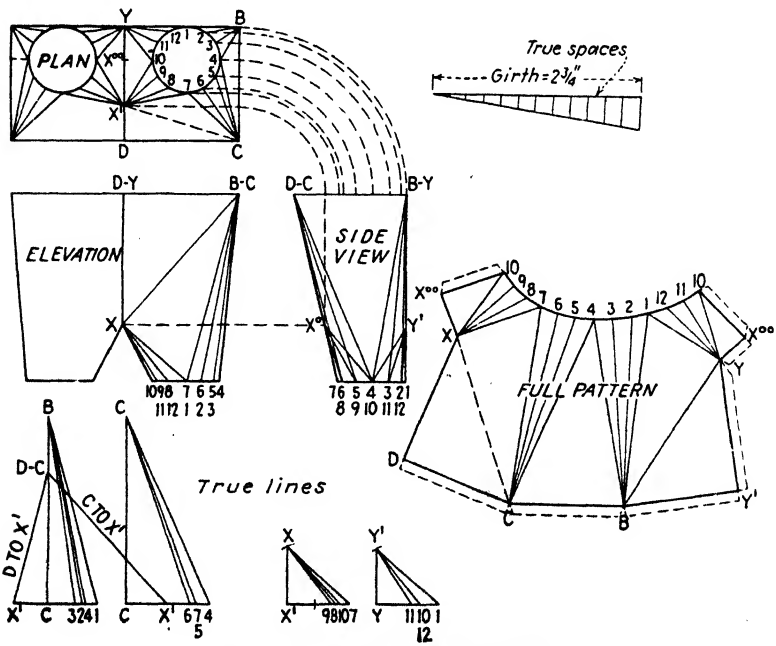


FIG. 111.—Straight-sided hopper.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 111

1. The front elevation is drawn first. The top or length of the rectangular end is to be selected conveniently, as well as the diameters of the round ends.

2. Point X is located in the elevation appropriately.

3. Directly above the front elevation draw the plan. Locate the circles straight to the back of the hopper.

4. By right-angle projection, CB of the plan is located in the side view. Likewise lines are projected from numbers on the circle in the plan, locating 7, 6, and 8, 5 and 9, 4 and 10, 3 and 11, 2 and 12, and point 1.

5. Point X of the elevation is projected to the side view, locating $X°$ and Y'.

6. Project $X°$ to the line CB in the side view. By right-angle projection from this point, X' is located in the plan.

7. Arrange the base lines in the plan as shown. The lines are arranged in the side view to correspond with those of the plan. Number them accordingly.

8. The drawing shows that there are three altitudes from which the true-surface lines are to be found.

The altitudes or straight heights for B and C are the same, and serve the base lines of the plan B to 1, 2, 3, 4; and C to 4, 5, 6, and 7. The altitudes from D to X and from C to X are the same, and serve the base lines of the plan C to X' and D to X'.

The straight heights from $X°$ and Y' in the side view serve the base lines of the plan X' to 7, 8, 9, and 10; and Y to 1, 12, 11, and 10.

9. All the lines in the pattern shape are different. To start the pattern, therefore, draw a horizontal line equal to the width of the rectangle CB in the plan.

10. With C as a center, in the pattern shape, and $C4$ of the true lengths as a radius, draw an arc. With B as a center and $B4$ of the true lengths as a radius, draw another arc. The intersection of the arcs will establish point 4 in the pattern shape.

11. Follow the order of lines as arranged, and place them in position, for the rest of the pattern.

NOTE: As the line YY' has no base line, this line (YY') in the side view is a true length.

EXERCISES

1. Figure 109 shows the development of a tapering compound-curved elbow. Make a drawing of a similar elbow to the following measurements:

Size of rectangular pipe in elevation	= $1\frac{1}{2}$ by $\frac{3}{4}$ in.
Throat radius in elevation	= 1 in.
Size of rectangular profile in plan	= $1\frac{3}{4}$ by $\frac{1}{2}$ in.
Throat radius in plan	= 1 in.

2. Make a similar drawing of Fig. 110 to the following dimensions:

Throat radius	= $\frac{7}{8}$ in.
Size of pipe in side and front views	= $1\frac{3}{4}$ by $\frac{3}{4}$ in.

3. Figure 111 shows a straight-sided hopper whose top measures 3 by $1\frac{1}{2}$ in. The round pipes measure $\frac{7}{8}$ in., and the straight height is $2\frac{1}{2}$ in. Make a similar drawing with diameters of 1 in. The other dimensions remain the same.

CHAPTER XV

DESIGNING TRANSITIONAL ELBOWS

In all work in which triangulation is applied, the principal use of the developments is in designing. This chapter treats of the designing of any type of transitional elbow consisting of more than three pieces, and discusses a method which simplifies such developments.

To introduce this simplified method a square-to-round elbow has been selected as shown in Fig. 112. If an elbow is to be made like those in Fig. 114, 115, or 116, the same method of designing and developing the sections will be used.

Figure 113 shows the development of a ship ventilator. Standard proportions must be applied to this type of elbow, as it has an overhang equal to one-third of the diameter, and the mouth is to be twice the diameter.

Figure 119 introduces a quick way to make a transforming elbow without the use of miter lines.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 112

1. In the first place, draw a right angle, and from its apex, *X*, draw the center line, locating points *A* and *E*.

2. Draw the half profiles of the ends.

3. To locate the miter lines the protractor may be used. As the elbow has four pieces, there will be a full count of six (page 17). Therefore, 90 ÷ 6 or 15 deg. is the rise of the first miter. See Chap. II.

4. Erect a perpendicular line from *A*, thus locating *B*, on the 15-deg. miter line. A horizontal line drawn from *E* will locate *D* on the 75-deg. miter line.

5. Lines drawn from *B* and *D* tangent to the back of the center line arc will locate *C*. Centers have now been located at *A*, *B*. *C*, *D*, and *E*.

6. Measure the girth of the centers between *A*, *B*, *C*, *D*, and *E*, and place them on a perpendicular line, as shown in the diagram marked side 1 in Fig. 112.

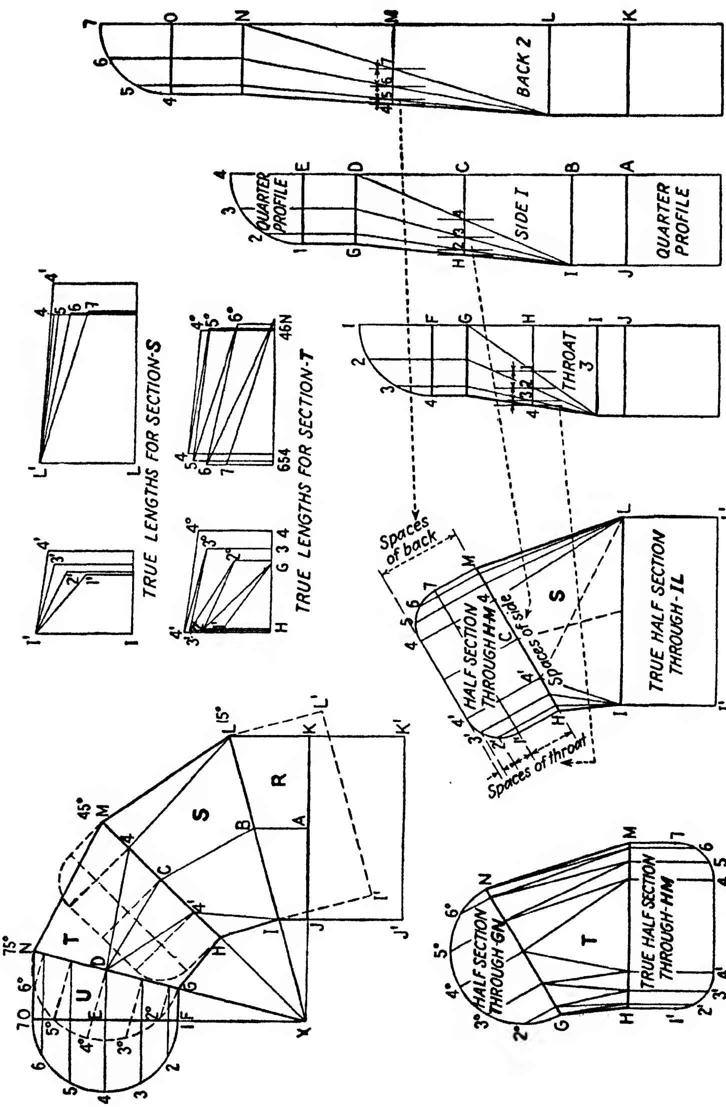


FIG. 112.—Square-to-round 90-deg. elbow—four pieces.

7. Place the quarter profile of the ends in the diagram. Horizontal lines drawn from *D* and *B* will intersect perpendicular lines drawn from *J* and 1, locating *G* and *I*. A line drawn from *I* to *G* will cut the horizontal line drawn from *C*, locating *H*.

8. A line drawn from *I* to *D* will complete the diagram of the side. With *C* of the elevation as a center and a radius equal to

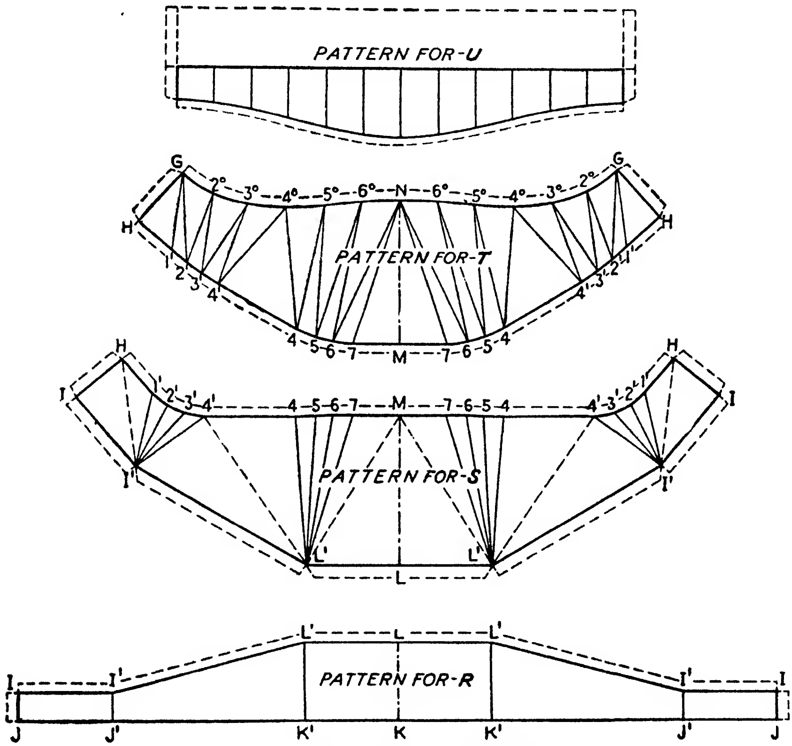


FIG. 112*a*.—Elbow patterns.

CH of the diagram, *H* and *M* are located on the 45-deg. miter line.

9. The width of the flat surface in the side diagram *C*4 is placed in the elevation on the 45-deg. miter line, locating points 4′ and 4.

10. Connecting points *F* to *G*, *G* to *H*, *H* to *I*, and *I* to *J* will complete the throat outline. Likewise, lines drawn from *K* to *L*, *L* to *M*, *M* to *N*, and *N* to *O* will complete the back outline of the elbow.

11. Lines drawn from E to D, D to 4, 4 to L, I to $4'$, and $4'$ to D will complete the flat surface through HM.

12. As the elbow ends are parallel forms, the true sections of the miter lines through IL and GN are developed in the usual way. Lines are drawn at right angles to I and L in the elevation. With the distance from the center to the outer edge of the profile J to J' and with I and L as centers, I' and L' are located, thus completing the section of the square end through IL.

From intersecting points at the miter, through GN of the elevation, lines are drawn at right angles to the miter. The distance from the center to the outer edge of the end profile, when placed on similarly numbered lines, will complete the section of the round end through GN.

NOTE: When a square-to-round elbow is required to have more than four pieces, diagrams are necessary for the development of the flat surfaces on the throat and back.

In this problem, the elbow has four pieces, and one end is square. Therefore, only the side diagram is required, as the flat surfaces for the back and throat are the same as the side. However, the diagrams for the throat and back are shown.

To develop the diagrams, the girths of the back and throat in the elevation are taken as at O, N, M, L, and K for the back, and J, I, H, G, and F for the throat.

In this problem it will be found that the flat surfaces of the back, throat, and side measure the same, as $4C$ of the side equals $M7$ and $H1$ of the throat and back. If the elbow were to have five pieces, the flat surfaces would be of different widths, and *three* diagrams would be necessary.

13. Transfer the middle pieces (S and T of the elevation) and arrange them on the paper as convenient. Place the true sections of the miter lines GN and IL in position.

NOTE: To develop the true half section of the miter line through HM, section S, place the spaces of the back, side, and throat into position, as indicated by arrows.

14. Lines drawn from the back to the throat positions will intersect lines drawn at right angles from the position on the miter line HM, thus completing the section. The curve is found by trial in elbows having more than four pieces.

15. Arrange the lines in pieces *T* and *S*, and develop the lines by sections.

NOTE: It is important that the girths of the pattern shapes are the same at their respective miters. The pattern shape *S* should have girths which equal 1, *I'*, and *L'* of the end pattern *R*; and spaces *H*, 1', 2', 3', 4'-4, 5, 6, 7, and *M* should likewise equal the spaces of the true half section through *HM*.

Make one end of the pattern *T* equal to the above girth through *HM*. The other end should equal the girth of the irregular-curved part of the elbow end marked *U* through *GN*.

It is always best to develop the end patterns first for all transitional elbows. Their girths at the miter line should be used for the middle pieces for those junctions where the middle piece joins the end piece.

By following the regular procedure for developing the lines by sections and placing them in the pattern shape in their respective order, as they are arranged in the transferred pieces marked *S* and *T*, no difficulty should be encountered in making accurate patterns.

INSTRUCTIONS FOR THE DEVELOPMENT OF A SHIP VENTILATOR—FIG. 113

1. According to standard proportions as explained in Supplementary Reference Sheet 14, design the elevation and front view (see Fig. 117).

2. To locate the miter lines, divide the arc of the throat into one less than the number of pieces required (in this case, four parts). Then divide each part again. The first space will be 11¼ deg.; the third will equal 33¾ deg.; the fifth, 56¼ deg.; the seventh, 78¾ deg. (The protractor may be used if desired.)

3. As the first piece of the elbow is a parallel form (page 4), erect a perpendicular line from points 7 and 1, intersecting the miter at 7' and 1'.

4. In the throat, the lines are straight and tangent to the inside of the arc. In the back, straight lines are drawn to the points of the intersection where the miter line penetrates the curve of the back arc, as indicated at points G^x, 7°, *G*, and 7.

5. Locate the center of each major axis as marked at 4, *D*, 4°, D^x, and 4'.

6. Lines drawn horizontally from these positions will penetrate the arc of the front view, locating the width of the minor

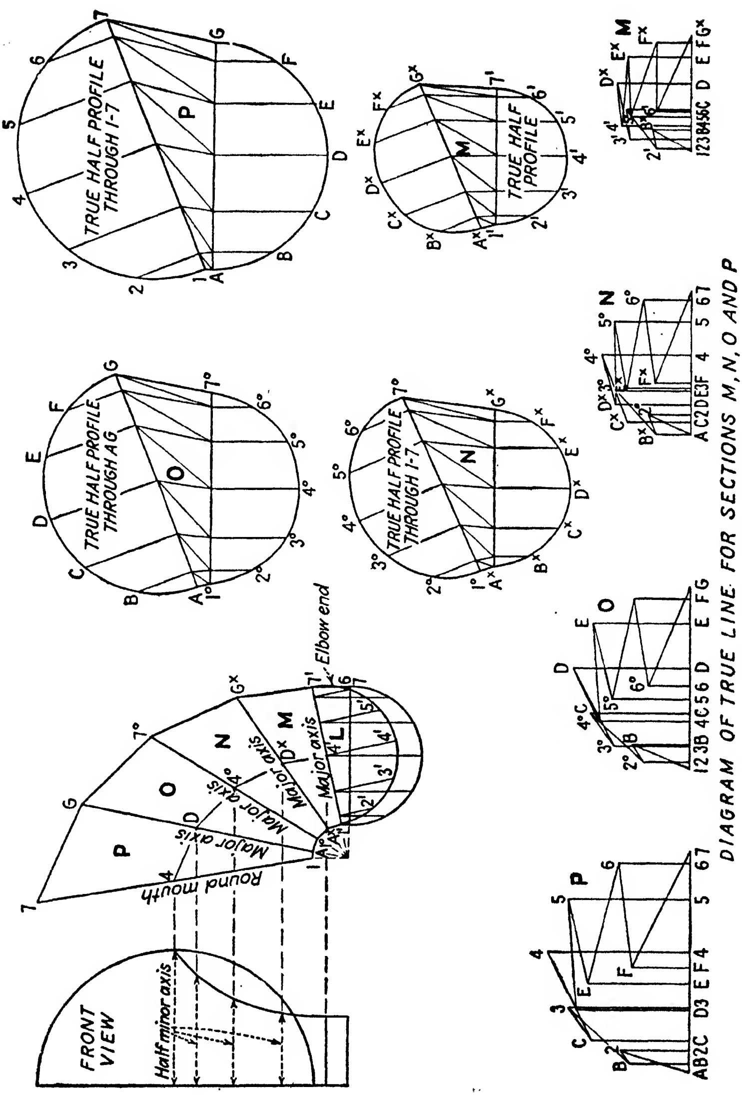


FIG. 113.—Ship ventilator.

axes as indicated by arrows. The curve for the side of the elbow is drawn conveniently in the front view.

7. The major and minor axes of each miter line are now determined, and an ellipse may be drawn for each junction through AG, $1°$-$7°$, and A^xG^x, as instructed in Supplementary

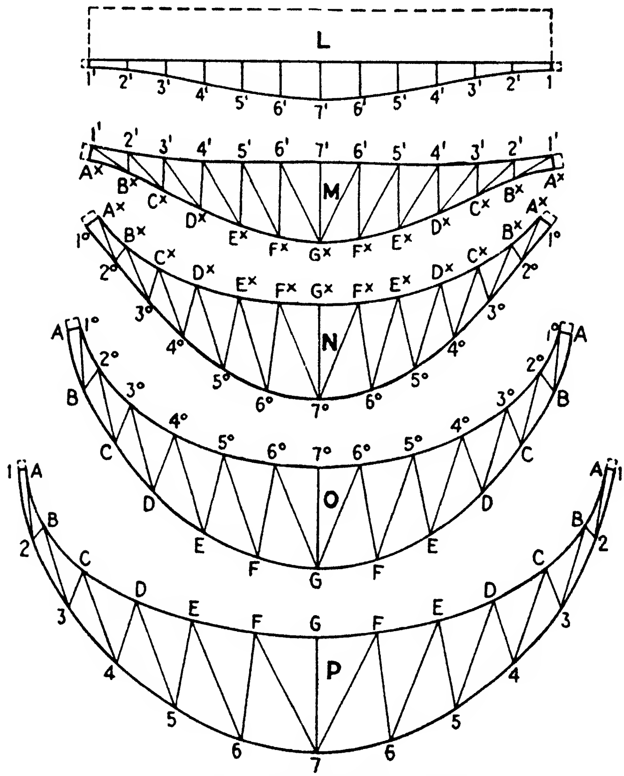


FIG. 113*a*.—Ship-ventilator pattern.

Reference Sheet 14. (It should be noted that the end profiles are round.)

8. Transfer each piece of the elevation, M, N, O, and P, conveniently on the paper, and place the true half sections in position.

NOTE: These pieces are taken out separately to avoid confusion of lines in the elevation.

9. Divide each section into six equal parts, and number each part as indicated.

10. Arrange the lines, and develop them by sections as the diagram of true lines shows.

11. Develop the round elbow end first. The girth of the miter 1′-7′ must be the same. Therefore, the girth of the pattern

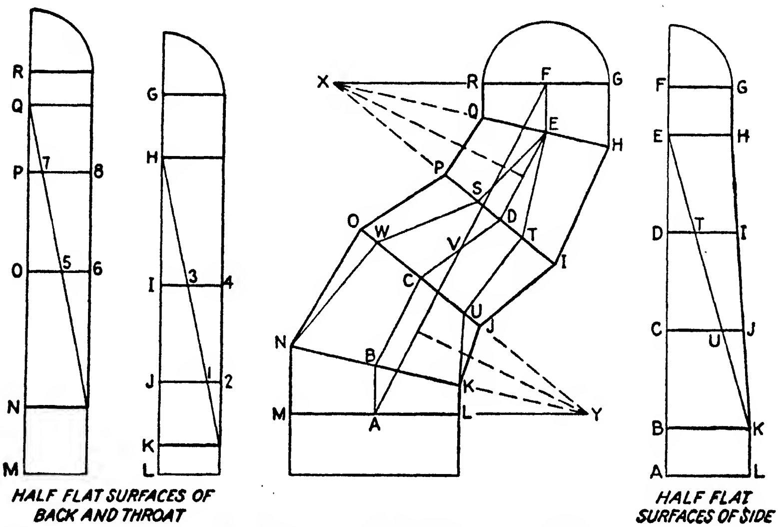


FIG. 114.—Five-piece square-to-round offset.

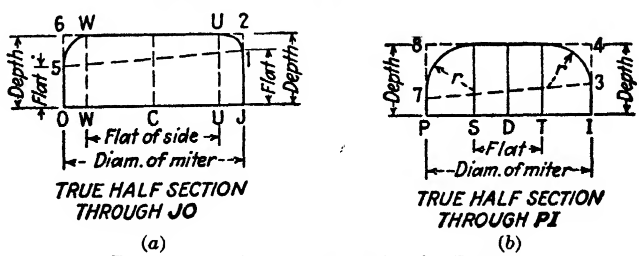


FIG. 114a and b.—True section for Fig. 114.

shape *M* (between 1′ and 7′) must equal the spaces between 1′-7′ of the elbow end.

12. All other girths are to be taken directly as they are spaced in the true profiles.

NOTE: It is realized that the arc is greater than the chord. For the middle sections of transitional elbows, however, it is permissible to use the spaces

directly off the profiles. That is, the girths of miters for pieces *M* and *N* through A^xG^x are to be equal. Elbow-end girths should always be computed to compensate for another pipe to fit them.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 114

Supplementary Reference Sheet 16 presents a good method of designing any offset that is to have more than three pieces, regardless of whether or not the elbow is a parallel form.

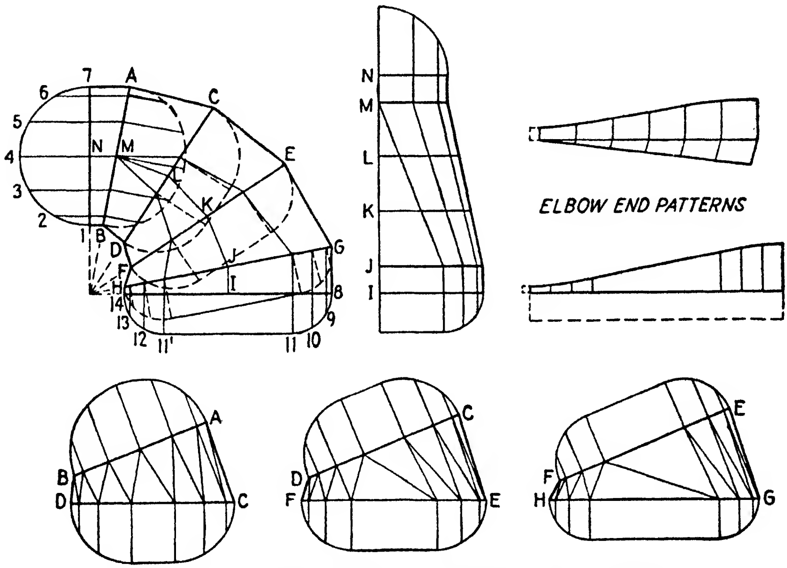


Fig. 115.—Five-piece oval-to-round elbow (on the sharp).

This method is also an efficient one for laying out curved offsets in square-pipe work. Figure 114 shows a square-to-round transitional offset in five sections.

1. Locate *X* and *Y* as instructed in Supplementary Reference Sheet 16, and draw the center-line curve.

2. To obtain the miters for the five pieces, divide the center-line curve between *A* and its center (marked *V*) into four equal parts. A line drawn from the apex *Y* through the first and third division points will show the miters for the lower half between *A* and *V*. The miters for the upper half between *V* and *F* are located in the same way.

3. Straight lines drawn tangent to the arc of the center line will locate *A*, *B*, *C*, *D*, *E*, and *F*.

4. *To complete the side elevation, the width of the flat surface on the side must be developed.* (See instructions—side *I*, Fig. 112.)

DEVELOPMENT OF TRUE HALF SECTION OF MITER LINE WHEN FLAT SURFACES ARE REQUIRED

Figures 114*a* and 114*b* show the true half sections for miters through *JO* and *IP*. These are the true shapes to be used for Fig. 114.

1. Take the diameter of the miter (Fig. 114) at *O*, *W*, *C*, *U*, and *J*, and place it on a horizontal line.

2. From the diagram of flat surfaces for the back and throat (Fig. 114) place the distance *O*, 5, 6, and *J*, 1, 2 in position. This will make the width of the flat surface on the throat *J* to 1 and the depth *J* to 2.

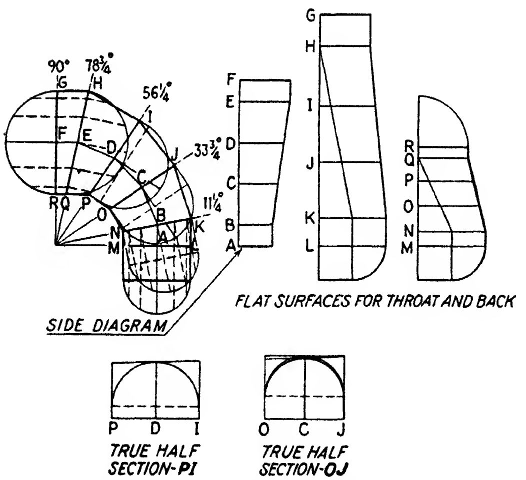


FIG. 116.—Five-piece oval-to-round elbow (on the flat).

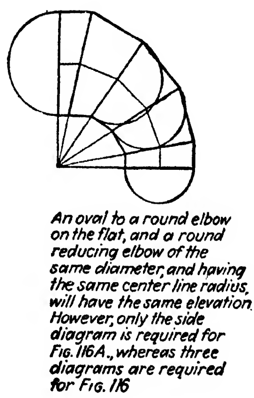


FIG. 116*a*.—Five-piece round reducing elbow.

3. Likewise, place the flat and depth of the diagram *O* to 5 and *O* to 6 in position.

4. A fair curve drawn between points 5 and *W* on the back and between point 1 and point *U* on the throat will complete the section.

NOTE: The radius for the curve is found by trial, and the section, Fig. 114*b*, is found in the same way.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 115

Figure 115 shows an oval-to-round elbow on the sharp. As the flat surfaces are on the side, only one diagram is required.

The method for designing and developing this elbow is similar to that for Fig. 112.

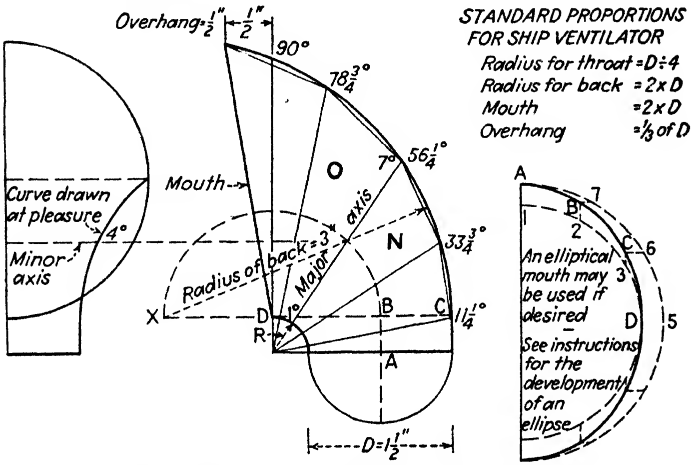


FIG. 117.—Standard proportions for a ship ventilator.

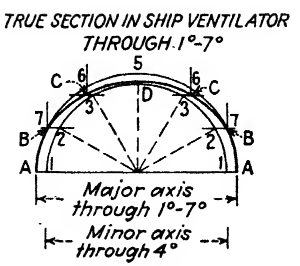


FIG. 117*a*.—True section in ship ventilator through 1°-7°.

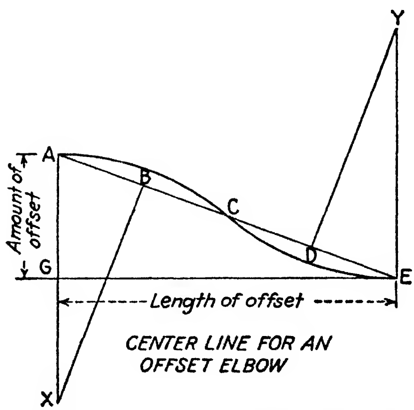


FIG. 118.—Center line for an offset elbow.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 116

This case is an elbow with flat surfaces at the back and in the throat. Three diagrams are necessary for this type. The

procedure for designing the elbow is similar to that for Figs. 112 and 114.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 119

1. To design this elbow, draw a right angle as indicated at $LG°$ and $A°$. With L as a center and $LA°$ as a radius, draw the arc of the back.

2. Draw a perpendicular line parallel to line $LA°$. This measurement represents the depth of the transition.

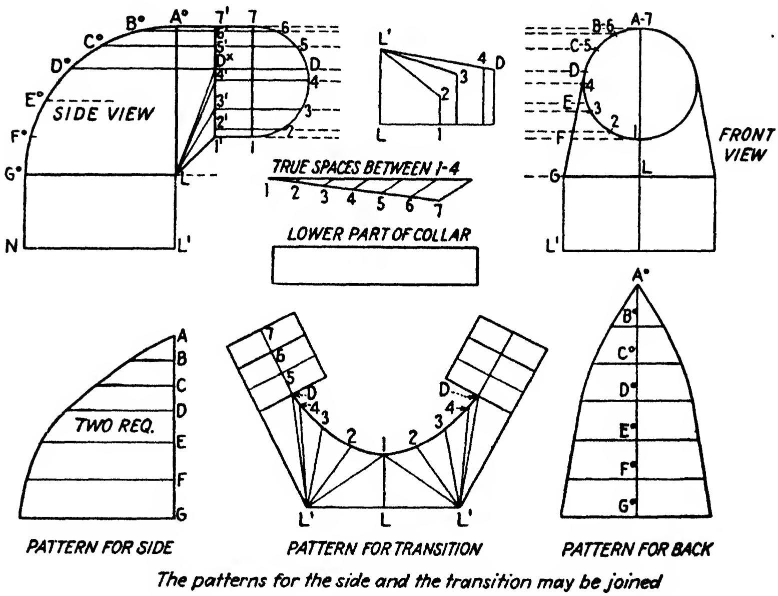


FIG. 119.—Simplified method for making a square-to-round elbow.

3. On this line lay off the diameter of the round end. This will locate points 1′ and 7′.

Draw the collar and the profile, but do *not* divide the profile in this step.

4. A line drawn from 1′ to L and from 7′ to $A°$ completes the elevation. LL' and $G°N$ represent half of the profile of the square end.

5. To construct the front view, a line is drawn from G tangent to the circle, which will locate the point marked D.

6. Divide the curve from D to 7 into three equal parts, as indicated at D, 5, 6, and 7.

7. From point 1 in the end view, divide the quarter circle as indicated at 1, 2, 3, and 4.

8. Points of the circle in the front view are then projected to line $1'$-$7'$ in the elevation, as indicated at $7'$, $6'$, $5'$, D^x, $4'$, $3'$, $2'$, and $1'$.

9. Divide the side view between $D°$ and $G°$ into three equal parts, as indicated at $D°$, $E°$, $F°$, and $G°$.

10. From points $D°$, $E°$, $F°$, and $G°$ lines are projected to the front view, establishing D, E, F, and G.

11. To develop the pattern of the back, the girth of the side view is placed under the front view. Horizontal lines drawn from $A°$, $F°$, $E°$, $D°$, $C°$, $B°$ will intersect similarly numbered lines drawn from the front view.

12. To develop the side pattern, take the girth of the front view A to G and place it directly under the side view on an extended line drawn from $A°$ to L.

13. Horizontal lines drawn from these positions will intersect similarly numbered lines drawn from the side view.

14. The pattern for the transition is an ordinary square-to-round one with a straight part added for the upper part of the collar.

The girth of the straight part D, 5, 6, and 7 is equal to the girth 7, 6, 5, and D in the side-view profile.

15. The lower part of the collar is a straight piece equal to the girth of the pattern as marked at D, 4, 3, 2, etc., to D.

SUPPLEMENTARY REFERENCE SHEET 14

Ship Ventilator

To design Fig. 117, the standard proportion as given below for that figure must be followed:

Throat radius	= $\frac{1}{4}$ of diameter.
Mouth	= approximately 2 × diameter.
Overhang	= $\frac{1}{3}$ of diameter.

To obtain the radius of the back, erect a perpendicular line from A to B, and with D as a center and DB as a radius the center point X is established. With X as a center and XC as a radius, draw the arc of the back.

The miter lines may be established by using the protractor. Disregarding the overhang, there is a full count of 8 and $\frac{90}{8}$ = $11\frac{1}{4}$ deg., which is the rise of the first miter.

Development of True Shape of the Section at Miter for Ship Ventilator

In Fig. 113, there are three developed sections through A^xG^x, 1°-7°, and AG. All of them have a major and minor axis. They are elliptical in shape. Figure 117a shows the true half shape that is used for one end of O and N through 1°-7°. Figure 113 shows the true half shape through 1°-7° in position. The development of an ellipse follows:

1. Draw a semicircle equal to the major axis (Fig. 117a).
2. Draw a semicircle equal to the minor axis (Fig. 117a).
3. Divide each half circle into six equal parts, as shown at points A, 7, 6, and 5 for the major circle and at 1, 2, 3, and D for the minor circle.
4. Draw horizontal lines from point 3 and point 2 in each quarter circle.
5. Draw perpendicular lines from point 6 and point 7. The intersection of the lines will produce points B and C in each quarter.
6. A fair curve through these points will give the true half shape of the profile, to be used at 1°-7° (Fig. 113).

SUPPLEMENTARY REFERENCE SHEET 15

Design of Elbow of Any Shape

This chapter was prepared to show how any shaped elbow may be designed. The following steps may be of some help in explanation given in the instruction sheets. Use this sheet in conjunction with Figs. 112, 114, 115, and 116.

1. Draw a center line and locate the profiles of the ends of the elbow.
2. Compute the miter lines (use of protractor).
3. Draw lines tangent to the center-line arc. This will provide a correct center for each miter.
4. The girth of the center (lengths of tangent lines) is placed on a perpendicular line. (See Fig. 112, side 1.)
5. The profiles are placed at the ends of this girth.
6. The end pieces of all transitional elbows are parallel forms. Perpendicular lines, therefore, are drawn to the first miter in the diagram.
7. Connecting lines of the first miters will complete the diagram of the side. If the elbow has flat surfaces, this line will also have to be shown.
8. To complete the side elevation, the widths of the diagram at the miters are taken and located in the elevation, equally spaced on either side of the center at their respective numbers.
9. Lines drawn to positions arranged will complete the elevation.

The above steps simplify the designing of transitional elbows and provide a quick method of averaging the correct lengths between the miters.

SUPPLEMENTARY REFERENCE SHEET 16

Design of Curved-line Offset

Figure 114 shows a square-to-round offset in five pieces, and Fig. 118 shows how this center line is obtained.

1. Draw a right angle equal to the width and length of the offset as at A, G, and E.

2. Draw a line from A to E, and divide this line into four equal parts as indicated at A, B, C, D, and E.

3. At right angles to line AE draw lines from points B and D, which will intersect extended lines drawn from G and E, thus locating X and Y.

4. With X as a center and XA as a radius, draw an arc.

5. With Y as a center and EY as a radius, draw another arc.

6. If the arcs do not meet at the center, C, the apexes X and Y have not been properly located. The arcs should always meet at C.

EXERCISES

1. The development for a four-pieced 90-deg. square-to-round transitional elbow is shown in Fig. 112. The elbow is designed to the following dimensions:

Center-line radius = $2\frac{1}{4}$ in.
Square-pipe size = $2\frac{1}{8}$ sq. in.
Round-pipe size = $1\frac{5}{8}$ in. in diameter.

Design a similar elbow of the same dimensions. However, instead of an elbow made into four pieces, design one that will have five pieces, and develop the pattern shape.

2. Assuming your own dimensions, design a square-to-round offset like Fig. 114. Compute the size of the round pipe so that the square pipe will have the same area as the round.

3. Design the elevation of a ship's ventilator having an elliptical mouth. Assume that the diameter of the round end is to measure $1\frac{3}{4}$ in. in diameter. Make the elliptical mouth $3\frac{1}{2}$ by $2\frac{1}{4}$ in.

NOTE: In Fig. 113 the mouth is round. Changing the shape of the mouth from round to elliptical will not affect the drawing.

CHAPTER XVI

AIRPLANE SHEET-METAL DRAFTING

This chapter treats of work in airplane development. The following pages relating to airplane construction in sheet metal were selected with a view to presenting only those examples of developments which are not "pressed," and which require a knowledge of layouts for repair work.

It is assumed that the all-metal aircraft companies have standardized their equipment for most of the component parts of the airplane. The ribs are usually in the form of thin metal bulkheads with flanged lightening holes. The cowling and parts with complicated contours are accurately fabricated in gigs and in hydraulic presses.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 120

Gasoline tanks for airplanes are made in various shapes and sizes. This drawing shows a gasoline tank with a chamfered end. It is made to fit into a definite part of the airplane. When the end of a round tank has to be cut in the form of an oblique, a *chamfer* can be used which will allow for extra capacity.

1. The drawing is started by making a partial side view of the tank. It is assumed that the chamfer is to be at 60 deg. from the center line of the tank, as indicated at $A1$.

2. The true half section is a quarter circle of the same radius as the tank. With the point marked $5'$ as a center and the distance from $5'$ to 5 as a radius, draw the section and divide it into four equal parts (five division points) as at 5, 4, 3, 2, and 1.

3. The true half section drawn through $A5'$ is a rectangle equal to half the diameter of the tank. Draw the half section in position, as indicated at AB and $5'C$.

4. Arrange the lines in the elevation, and develop them by sections as the diagram of true lines shows. The order of these lines is A to 1, B to 1, B to 2, B to 3, B to 4, B to 5. This is the order in which they are placed in the pattern shape.

The pattern shape is found by using the methods explained in preceding chapters. It should be observed that this case is like a square-to-round transition.

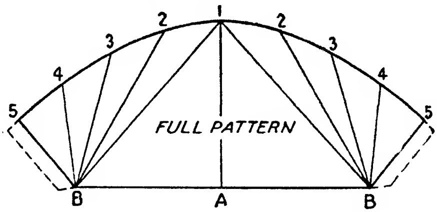
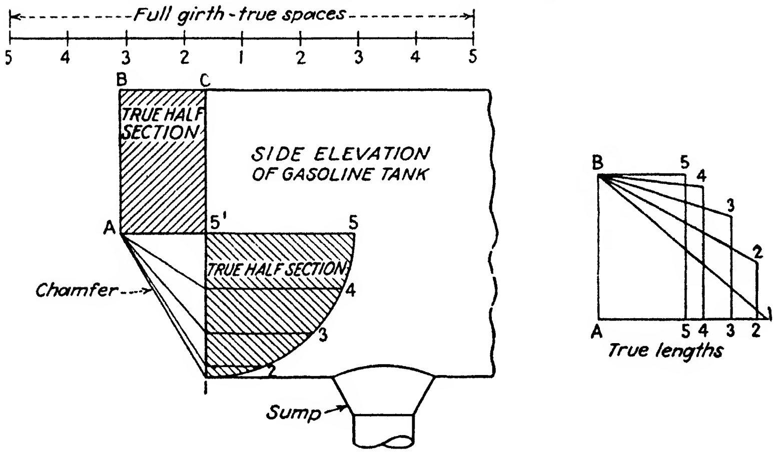


Fig. 120.—Chamfer pattern for a round gasoline tank.



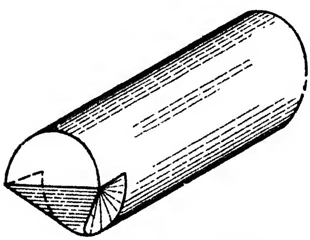


Fig. 120a.—Sketch of gasoline tank.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 121

This drawing shows the development of a sump in a gasoline tank. If the shape of the cross section were elliptical instead of round, the same method that is explained here would be used in its development.

1. Draw the frustum of a cone intersecting a cylinder at 90 deg., as shown by the end view of the *tank*.

2. Draw the plan, and divide each quarter into three equal parts. Mark the small circle by numbers 1, 2, 3, and 4, and the large circle by letters *A*, *B*, *C*, and *D*.

3. Arrange the lines of the plan. From points, as numbered in the preceding paragraph, draw perpendicular lines to the elevation, as indicated at 1, 2, 3, and 4, and at *D′*, *C′*, *B′*, and *A′*.

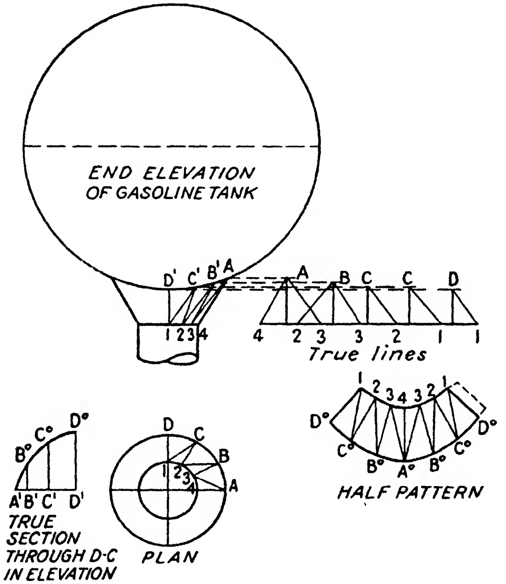


FIG. 121.—Development of a sump.

4. Make a diagram of true lines. The plan will provide the base lines, and the elevation the various altitudes of triangles—the hypotenuse of which is the true length.

5. Draw the true lines in the pattern shape according to the order of the lines, as arranged. The spaces between points 1, 2, 3, and 4 equal the quarter girth of the round end. However, the curved end will equal the girth of the true section, which is found in the next step as follows:

6. Take the girth of the curved line in the elevation, the spaces of which are *D′* to *C′*, *C′* to *B′*, and *B′* to *A′*, and place the spaces on a horizontal line extended from the center line of the plan.

From these positions erect vertical lines. Horizontal lines drawn from *D*, *C*, *B*, and *A* will intersect positions at *D°*. *C°*. *B°*

and $A°$, completing the true spaces to be used in the pattern shape.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 122

This type of long-radius elbow is encountered in all kinds of ventilation work and is likely to occur in the heating and ventilating system of a transport airplane.

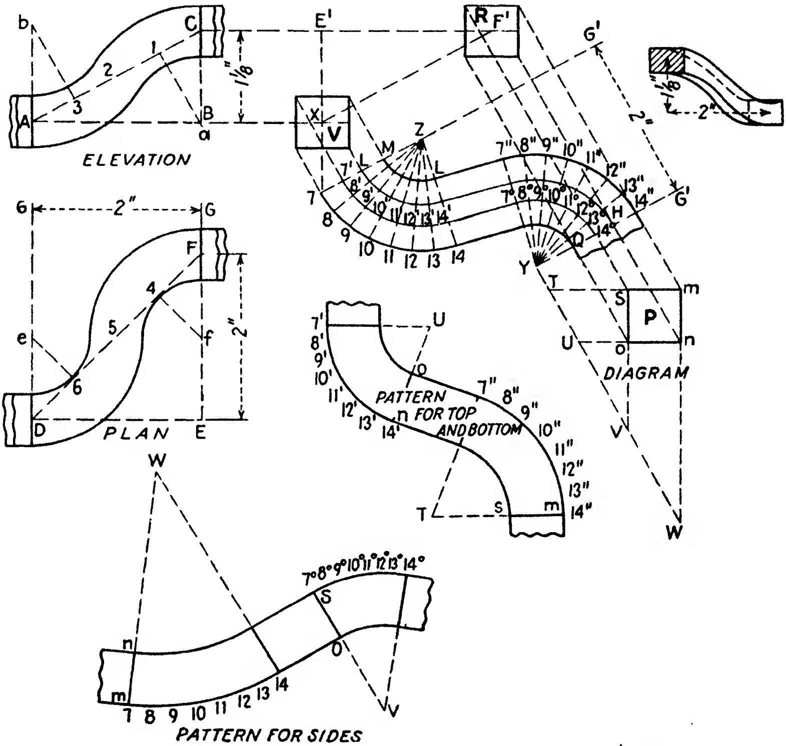


FIG. 122.—Compound offset in square pipe developed from the diagonal view in the elevation.

Such designs offer excellent opportunities for developing the pattern shapes for any kind of double offset in square or rectangular pipes.

1. According to instructions given in Chap. XV, Supplementary Reference Sheet 16 (Fig. 118), draw the elevation and the plan.

2. On extended lines drawn from A, B, and C in the elevation, place the profiles V and R. The horizontal distance between the

centers of these profiles equals *EF* of the plan, as indicated at *E′F′*.

3. Draw a diagonal line to center points of the square pipe, as indicated at *XF′*. Draw another line parallel to *XF′*, as indicated at *7G′*. The depth of the offset *G′G′* is equal to *GG* in the plan.

4. From all corners of the square marked *V* lines are drawn at right angles to *XF′*, intersecting line *7G′* at 7, 7′, *L*, and *M*. Draw lines from all corners of the square marked *R*, which will intersect the line *YG′*, locating *Q*14°, *H*, and 14″.

5. Radiuses *Z* and *Y* are selected conveniently. That is, any radius that will suit the depth *GG* will be satisfactory.

6. With *Z* as a center, and from points *M*, *L*, 7′, and 7, draw the arcs of the back, sides, and throat. Likewise, using *Y* as a center, draw the arcs of the lower end. A line drawn tangent to the back of the arcs will complete the side view as seen cornerwise.

7. A line drawn from the centers *Z* and *Y* to the intersections of the tangents, as marked at 14 and 7″, will form parallel lines. That is, *Z*14 should be made parallel to *Y*7″.

8. Divide the curve between 14 and 7 into seven equal parts, and number each division as indicated. Likewise, divide the curve between 14″ and 7″ into seven equal parts, and number each division as indicated at 13″, 12″, etc.

9. Lines drawn from the apex *X* and *Y* to points of the back arcs will intersect the curved lines, locating points 14′, 13′, 12′, etc., and 14°, 13°, 12°, etc.

10. By drawing extended lines of the square pipe *R*, the square pipe *P* is located as marked at the corners *m*, *n*, *o*, and *s*.

11. A line drawn from *Y* and parallel to extended lines from *R* will intersect perpendicular lines extended from *s*, *o*, and *m* and *n*, thus locating *V* and *W*.

12. Horizontal lines from *m*, *s*, and *n*, *o* will intersect the extended line from *Y* at *T* and *U*.

13. In the diagram just completed, the distances to be used for the radiuses of the throat and back for the top and side patterns can be obtained.

Center	Throat radius	Back radius
T	*T* to *S*	*T* to *m* for top and bottom
U	*U* to *O*	*U* to *n*
V	*V* to *O*	*V* to *s*
W	*W* to *n*	*W* to *m* for side only

14. To develop the side pattern, take the radius W to n of the diagram, and draw the arc of the throat. With W in the pattern shape as a center and Wm of the diagram as a radius, draw the arc of the back.

15. Locate the girth on the back arc, using the spaces of the elevation between 7 and 14.

16. Draw a line from 14 to the apex W.

17. At right angles to $14W$, extend lines. Place the width of the flat surface equal to $L7''$ of the elevation in the pattern shape, which locates points 7° and O.

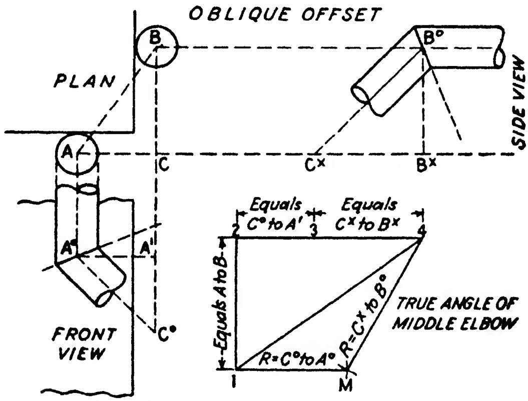


FIG. 123.—Compound offset in round pipe.

18. On an extended line of $7°O$, place the apex of the radius V. VO of the diagram should equal VO of the pattern shape.

19. With V as a center and VO as a radius, draw the arc of the throat. Using V as a center and VS as a radius, draw the arc of the back.

20. Place the girth of the elevation between 7° and 14° on the back arc of the pattern, and from 14° draw a line to V. This completes the pattern for the sides.

NOTE: Follow the same procedure for the development of the top and bottom patterns. The radiuses of the patterns are shown in paragraph 13. Similarly, the numbered girths are to be taken from the elevation as indicated in the pattern shape.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 123

The explanation given for this figure may be used for all oblique offsets in round-pipe work, wherever encountered.

The sketch shows an oblique offset in the heating system of a transport airplane.

Three views are required to develop the angle that the middle elbow is to have. The plan shows the angle of the partition and the position of the end elbows as indicated at A, B, and C.

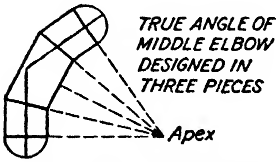


FIG. 123a.—True angle of elbow designed in three pieces.

The end elbows in the front and side views are drawn at 45 deg.

NOTE: The ends could be of any angle, and the method of obtaining the desired results would be the same. That is, one end could be drawn at 30 deg. and the other at 60 deg.

The purpose of locating the three views is to obtain measurements for the development of the angle for the middle elbow.

1. Draw the plan view, assuming suitable dimensions between AC and CB.

2. Draw the front and side views. The miter lines of the front and side views are found by bisecting the angle at A° and B°.

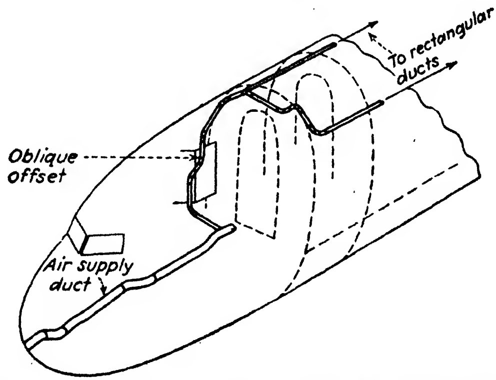


FIG. 123b.—Sketch of pipe line showing double offset.

3. Extend line CB of the plan into the front view. Line CB will intersect the 45-deg. line drawn from A°, as indicated at C°.

4. Extend line AC of the plan into the side view. An extended line from B° will locate C^{x}.

5. Draw a right angle, and make the distance between points 1 and 2 equal to the diagonal of AB in the plan.

6. The distance of the horizontal leg between points 2 and 3 equals $C^{\circ}A'$ of the front view; and the distance between points 3 and 4 is equal to $C^{x}B^{x}$ of the side view.

7. With point 4 as a center and a radius equal to C^xB° of the side view, an arc is drawn. Using point 1 as a center and with a radius equal to $C^\circ A^\circ$ of the front view, draw another arc, the intersection of which will locate M.

8. A line drawn from 4 to M and from M to 1 completes the true angle for the middle elbow.

NOTE: If the middle elbow is to have more than two pieces, the angle of the elbow should be bisected. From the apex, draw the center-line arc. By following the procedure for elbows given in previous chapters, the elbow can be made of any number of pieces as desired.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 124

In airplane design it is necessary that true curves be obtained for the development of the nose, and also for the various sections and bulkheads. This problem shows a simplified method for developing any true curve when the horizontal and crown distance is given.

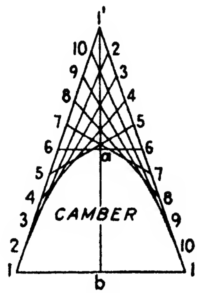


FIG. 124.—Camber.

The development of the camber serves an unlimited number of purposes and is used extensively in shipbuilding.

1. Draw the width of the camber as at 1-1, assuming suitable dimensions.
2. Let ab equal the depth of the camber.
3. On an extended line through ab, locate the depth of the crown as at 1′.
4. Draw lines from 1′ to 1, and divide the lines and number them as indicated.
5. Lines drawn diagonally and to similar numbers will complete the desired curve.

INSTRUCTIONS FOR THE DEVELOPMENT OF FIG. 125

This figure shows how the back of a pilot seat is developed. In this type of drawing, where the true length of the curve cannot be seen in either the plan or the elevation view, a true section must be developed which will provide the true girth to be used in the pattern shape.

1. Assume suitable dimensions for the elevation and plan views. Tangent arcs will provide the curves.

2. Divide the curves in the plan into equal parts, as indicated between 1 to 7 and *A* to *H*.

3. Extend lines from points *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H* in the plan to the curve of the back in the elevation.

4. Extend lines from 1, 2, 3, 4, 5, 6, and 7 in the plan to the bottom of the seat in the elevation.

5. Arrange the base lines of the plan 1 to *A*, *A* to 2, 2 to *B*, etc., and locate them in the diagram of true lines. Horizontal lines

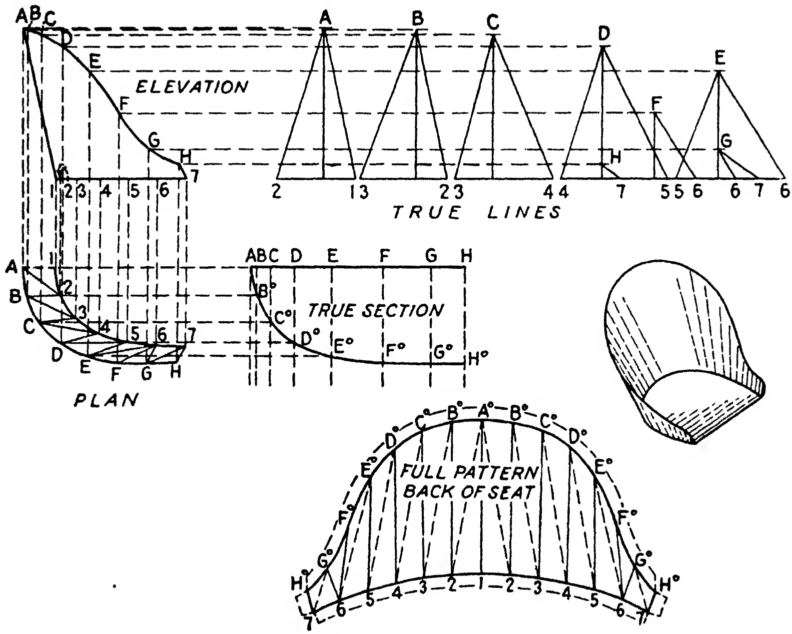


FIG. 125.—Pilot's seat.

drawn from points *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H* in the elevation will provide the various altitudes for the several base lines. The hypotenuse of the right-angle triangles will be the true length of the surface lines.

6. To develop the true section, spaces of the irregular curve in the elevation are located on a horizontal line extended from *A*1 of the plan. Horizontal lines from *A*, *B*, *C*, etc., of the plan will intersect lines drawn at right angles from similar letters in the section, completing the true spaces to be used in the pattern shape between *A*°, *B*°, *C*°, *D*°, etc.

7. Proceed with the pattern shape in the usual way. Care should be taken in picking off the proper spaces in the section to be used for the irregular-shaped curve of the back. The spaces for the bottom curve are to be taken from the plan between points 1 and 2, 2 and 3, etc., and used for the girth of the bottom.

EXERCISES

1. Figure 120 shows a gas-tank chamfered at 60 deg. Make a similar drawing of one at 45 deg.

2. Make the drawings for the elevation, plan, and pattern shapes for a double offset in square pipe, as shown in Fig. 122. Assuming that the distance between G' and G' is to be 3 in. instead of 2 in., make the distance between F and E 1½ in. instead of its present measurement of 2 in. Let all other dimensions remain the same.

3. Assuming your own dimensions, develop the angle of the middle elbow (Fig. 123*a*) and show how this angle is designed so that it will have four pieces.

CHAPTER XVII

SKYLIGHTS

One of the most interesting problems encountered in the sheet-metal trade is the development of the pattern shapes and the practical application of mathematics in determining the lengths of bars in skylights of the hipped type.

The supplementary reference sheets of this chapter provide a quick method of computing the lengths of various bars used in hipped skylights. It is important that Supplementary Sheets 17 and 18 be carefully studied before the reader attempts to lay out the pattern shapes. The bars shown in Figs. 141, 142, and 143 are the shapes required for the development of the hipped skylight in Figs. 126 and 127. Figure 127 shows a separate drawing for the development of the hip-bar pattern.

If the laying out of the hipped skylight is thoroughly understood, the reader should encounter no difficulty in laying out any other type of skylight, whether it is of the *flat*, *single-pitched*, or *double-pitched* kind. For example, if the pattern shapes of a flat skylight are required, the principles for laying out the curb and common bar are the same as those used for developing the common-bar and curb patterns of a hipped skylight.

The pattern shapes of a typical hipped skylight may be used for making all types of hipped skylights, square or rectangular in shape, provided they are all of the same pitch. That is, if a hipped skylight is of one-third pitch (page 167), the patterns acquired can be used for any hipped skylight of one-third pitch. If the pitch is other than one-third, a new set of patterns must be laid out. Figures 136, 137, 138, and 139 show plans of hipped skylights. It will be noticed that all the bars are arranged and spaced differently. However, this does not affect the pattern miters. The pattern shapes for Figs. 126 and 127 may be applied to skylights like those shown in the plans, assuming that these plans are to be of one-third pitch.

SPECIFICATIONS FOR ALL TYPES OF SKYLIGHTS

1. The curb should be provided with weep holes to let out condensation (see Figs. 126 and 140).

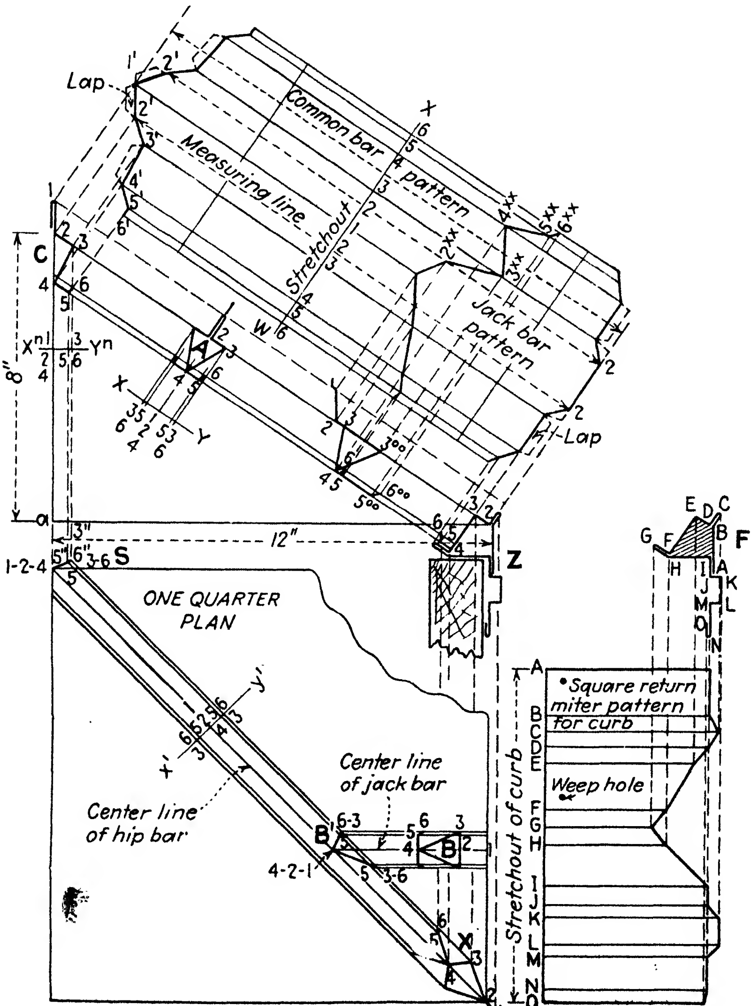


FIG. 126.—Development of bars for a one-third pitch skylight.

2. The bed of putty should be sufficiently heavy to give the glass an even bearing (see Fig. 140).

3. According to the National Board of Fire Underwriters, the bars in skylights should be spaced not more than 20 in. apart, and each pane of glass should not exceed 720 sq. in. in area.

4. If the panes exceed 720 sq. in. in area, a watertight crossbar must be provided (see Fig. 134).

5. Caps should be provided and fastened with bolts (see Fig. 134).

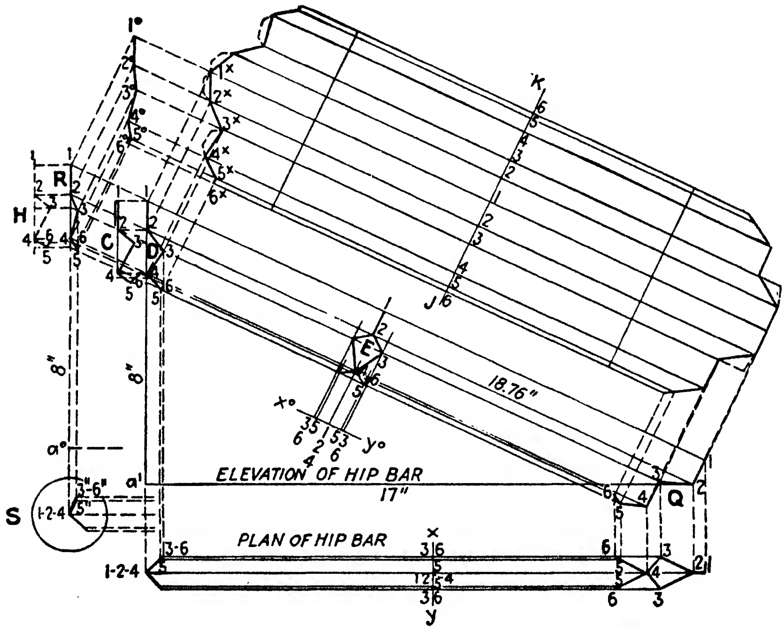


FIG. 127.—Development of hip bar for a one-third pitch skylight.

6. To provide for expansion and contraction, the glass should be cut $\frac{1}{8}$ in. smaller on all sides.

7. On large skylights the bars should be reinforced (see Fig. 135).

INSTRUCTIONS FOR THE DEVELOPMENT OF PATTERN SHAPES FOR A ONE-THIRD PITCH HIPPED SKYLIGHT—FIG. 126

1. The first step is to make a right-angle triangle, the altitude of which is to be 8 in. and the base 12 in., as indicated by the arrows at points *a* and 2.

2. One-quarter of the outline of the plan may then be drawn directly below the elevation. This will be a 12-in. square, which

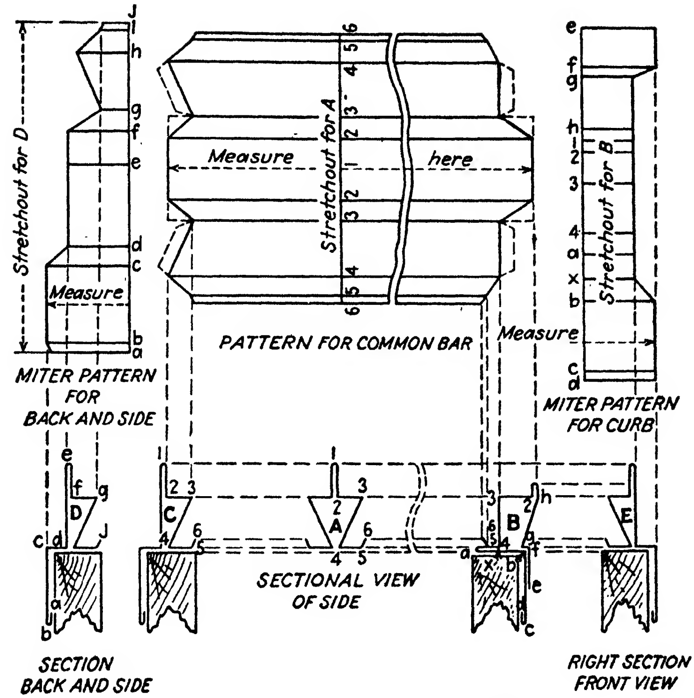


Fig. 128.—Development of flat skylight.

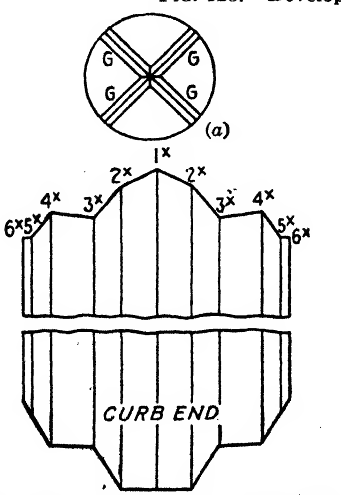


Fig. 129.—Intersecting hip-bar miter *G*. (*a*) Plan of hip bars *G*.

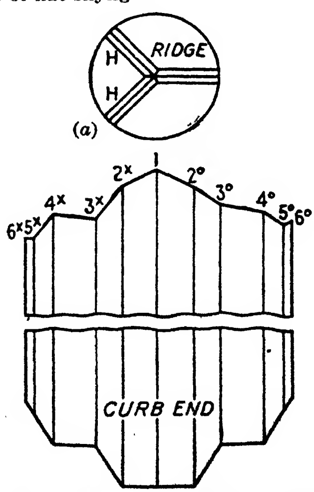


Fig. 130.—Intersecting hip-bar miters at hips and ridge *H*. (*a*) Plan of intersecting hip bars *H*.

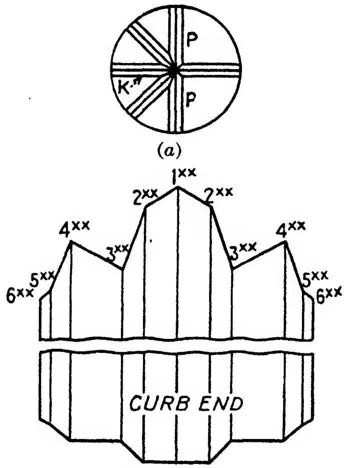


FIG. 131.—Intersecting center jack-bar miters *K*. (*a*) Plan of intersecting jack-bar miters *K* and *P*.

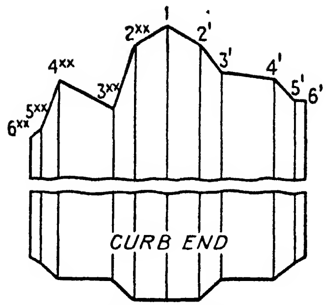


FIG. 132.—Intersecting common jack-bar miters *P*.

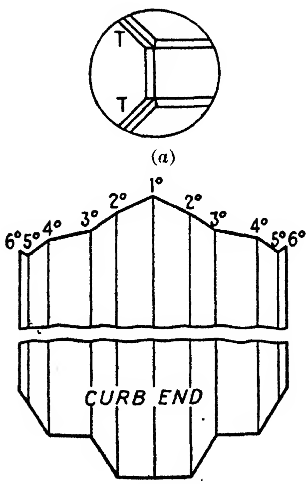


FIG. 133.—Intersecting hip-bar miters at ventilator-ridge bar *T*. (*a*) Plan view of ventilator ridge and hip bars *T*.

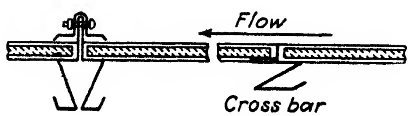


FIG. 134.—Crossbar.

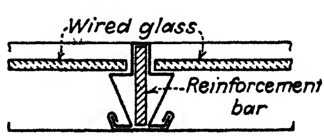


FIG. 135.—Reinforcement bar.

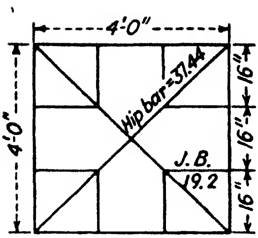


Fig. 136.

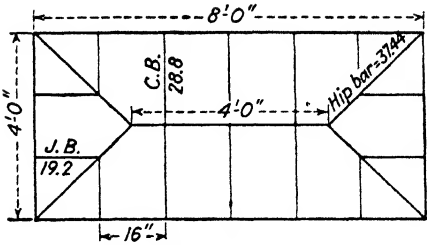


Fig. 137.

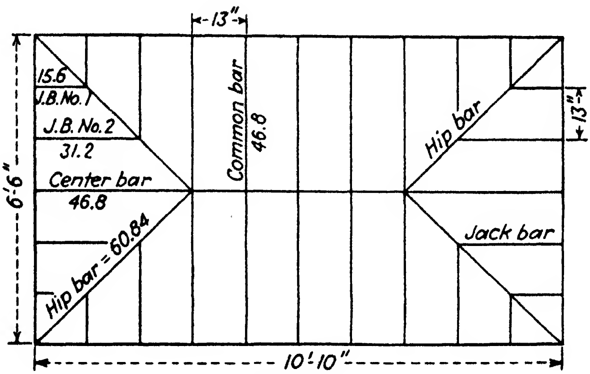


Fig. 138.

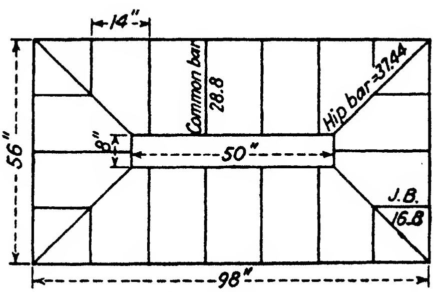


Fig. 139.

Figs. 136–139.—Plans of one-third pitch skylights.

will represent the plan. A diagonal line drawn across corners will represent the center line of the hip bar.

3. At a convenient place, draw a line at right angles to the outline of the curb in the plan view. This will represent the center line of *jack bar B*.

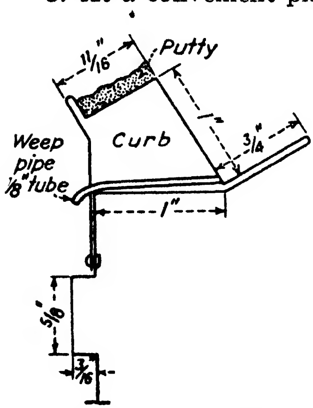


FIG. 140.—Sectional view of a curb.

4. On the line which is the hypotenuse in the elevation, draw at random a sectional view of the *common bar*[1] marked at A, Fig. 126 (see Fig. 141 for size of the bar).

5. A duplication of the sectional view of the common bar will form the shape of jack bar B in the plan.

6. The widths of the common bar A are placed at right angles to the center line of the hip bar in the plan; or the widths of the bar on the line XY, as marked in the elevation, can be transferred to the line $X'Y'$ in the plan as shown. Parallel lines are drawn from these points, locating points 1, 2, 4, 5, 3, and 6. The true shape of

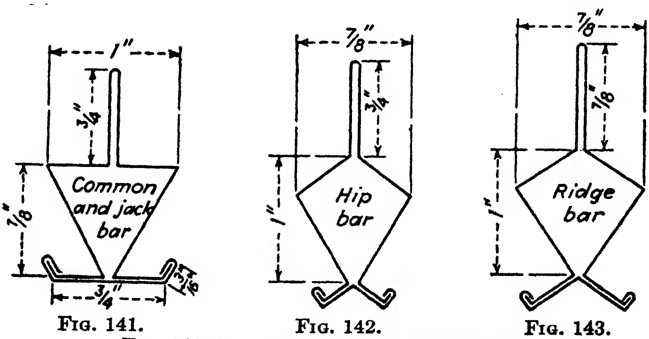


FIG. 141. FIG. 142. FIG. 143.
FIG. 141–143.—Sections of skylight bars.

the hip bar is developed in Fig. 127, and an approximate shape is shown in Fig. 142.

NOTE: Points 3'', 6'', and 5'' will be located in step 10.

7. Parallel lines drawn from section B will intersect similarly numbered lines of the hip, which will form the plan of the jack-bar

[1] Jack bars and common bars are always the same size and shape in the sectional view.

miter to be developed. These intersections are marked 1, 2, 3, 4, 5, and 6 on each side of the center line as marked B'.

NOTE: Points 6, 5, 4, 3, 2, and 1 in the lower right-hand corner X of the plan will be located in step 10.

8. To complete the elevation, a suitable curb must be drawn at Z.[1]

NOTE: The curb that is shown has a gutter at point 4 which is about ¼ in. below the gutter of the common bar at point 5.

NOTE: The gutter of the common bar at point 5 is cut back from the curb to points 5 and 6. This allows condensation to run out of the common-bar gutter.

9. To develop a half section of the ridge bar C, draw oblique lines parallel from points of the common-bar section A which will intersect lines drawn vertically from $x^n y^n$ locating points 1 to 6 in the ridge- and curb-bar sections (C and Z).

10. Lines extended from section C into the plan will locate points $5''$, $6''$, and $3''$ at S. Lines extended to the plan from points of the curb Z will locate points in the plan of the hip bar, as indicated by the intersections from points 1 to 6 at X.

11. To develop the common bar, take the girth of the common-bar section A and place it on a line drawn at random at right angles to line 2 of the elevation. This line is marked stretchout WX, and is numbered 6 to 1.

12. Parallel lines drawn from points 6 to 1 at right angles to the line WX will intersect similarly numbered lines drawn at right angles from the ridge C and the curb Z. This will locate the points of the common-bar pattern. Add laps as indicated.

13. To obtain the jack-bar miter cut, erect lines from the plan of the jack bar at the intersections marked B', 1 to 6, on either side of the center line, to similarly numbered lines in the elevation. This will locate numbers 1, 2, 3, 4, 5, and 6 for one side, and 1, 2, $3^{\circ\circ}$, 4, $5^{\circ\circ}$, and $6^{\circ\circ}$ for the other side.

14. Lines drawn at right angles from these points will locate the *miter-cut* pattern for the jack bar.

NOTE: All projecting lines must be parallel.

15. Transfer the section of the curb to one side as indicated at F, and mark each point of the section from A to O inclusive.

[1] See dimensions of bars, Fig. 139.

16. Take off the above spaces in alphabetical order and place them on a perpendicular stretchout line. Mark each division as indicated.

17. Lines drawn at right angles from the points *A* to *O* in the stretchout will intersect similarly numbered lines drawn vertically from the curb section. This will give the correct miter line, which will make a 45-deg. miter when the curb is formed.

INSTRUCTIONS FOR THE DEVELOPMENT OF THE HIP-BAR PATTERN—FIG. 127

To avoid a confusion of lines, it is better to make a duplicate plan for the hip bar. The plan in Fig. 127 shows the hip bar in a horizontal position.

1. Parallel to the lines of the plan, draw a line from a' to 2. This line will form the base of the elevation for the hip bar, and should measure 17 in.

2. A perpendicular line erected at right angles from point a' will represent the height. This line measures 8 in. between points a' and 2.

3. Draw a line from point 2 of the altitude to point 2 of the base, to form a right-angle triangle. The hypotenuse should measure 18.76 in.

NOTE: The next step is to develop the true section of the hip bar *E* and its ends *D* and *Q*.

4. Transfer the ridge-bar section *C* (Fig. 126) to the position marked *C* (Fig. 127) and place it in line with point 2.

5. Lines drawn horizontally from points of the ridge-bar section *C* will locate points on the vertical line a'-2, from which points oblique lines are drawn parallel to hip line 2.

Section *D* is located by extending points in the plan 1, 2, 3, 4, 5, and 6, to similarly numbered lines in the elevation.

6. From the curb end of the hip bar, erect vertical lines which will intersect similarly numbered lines drawn from points of section *D* to form the section marked *Q*.

NOTE: All lines must be parallel to the hypotenuse side of the right-angle triangle.

7. A duplication of the common-bar stretchout as at $X^{\circ}Y^{\circ}$ provides the positions from which lines are erected to intersect similarly numbered lines to form the section marked *E*.

8. The stretchout JK is taken from section E. Lines drawn at right angles from the diagonal side of the hip and from points of the sections marked D and Q will intersect similarly numbered lines of the stretchout. This completes the pattern shape of the hip bar.

9. When a miter line is desired to fit the hips and the ridge (see Fig. 130*a*), the extended sections S and H (Fig. 127) are required to locate the miter cut R. In this case H is the same as the ridge section C; and section S is a result of the projection from points of the ridge to similarly numbered points of the plan, locating points 5″, 6″, and 3″ (Fig. 126). Points 1, 2, and 4 remain the same for all cuts.

10. One-half the miter pattern for Fig. 130 is developed in Fig. 127 as follows: Lines are extended at right angles from the center line of the hip bar in section R to similarly numbered lines of the stretchout, which will locate 1°, 2°, 3°, 4°, 5°, and 6°.

INSTRUCTIONS FOR THE DEVELOPMENT OF THE FLAT SKYLIGHT—FIG. 128

1. The first step is to draw the sectional view, locating the curb bar for the front B and the curb bar for the back C.

2. Draw a full section for the common bar A, and place it at any convenient place between points B and C. Number the section 1 to 6.

3. Lines drawn horizontally from points of section A will intersect sections C and B. Number the intersections 1, 2, 3, 4, 5, and 6. Notch back the intersection at points 5 and 6, where they intersect the curb B. This is done to allow the condensation to run out of the common-bar gutter into the curb gutter.

4. At right angles to lines in the sectional view, draw a line, and place the stretchout of section A on this line, numbering the divisions on either side of the center from 1 to 6.

5. Lines erected from points of sections C and B will intersect similarly numbered lines drawn horizontally from points of the stretchout, which will locate the cuts for the common-bar pattern. A line drawn through these points will complete the pattern shape for the common bar.

6. To obtain the miter cut for the back and side patterns, place the section marked D on a horizontal plane in line with section C. Mark each point from a to j.

7. Draw a stretchout line for section *D*, and place the divisions on this line as marked from *a* to *j*.

8. Lines drawn at right angles from points of the stretchout will intersect similarly numbered points erected from section *D*. This will complete the pattern shape required for the back and sides.

9. To obtain the miter pattern for the front curb, place a duplicate of section *C* in a parallel line with section *B*, as marked at *E*.

10. Mark each point of section *B*, and place these divisions on the line marked stretchout *B*.

11. Horizontal lines drawn from points of the stretchout will intersect similar points of intersection drawn from section *E*. A line drawn through these points completes the miter cut for the front curb.

SUPPLEMENTARY REFERENCE SHEET 17

Usually the pitch of a hipped skylight is one-third the width of the skylight, or the rise is 8 to 12 in. The width of 12 in. will suffice to lay out any hipped skylight, whatever the pitch is to be. If a one-quarter pitch is desired, the altitude will measure 6 to 12 in., as $24 \div 4 = 6$.

Figures 126 and 127 show the development of a hipped skylight of one-third pitch. The sectional view of half the end elevation has an altitude of 8 in. and a base of 12 in. The four bar shapes of the hipped skylight are as follows:

1. Curb or base (Fig. 140).
2. Hip bar (Fig. 142).
3. Jack bar (Fig. 141).
4. Common bar (Fig. 143).

NOTE: The common- and jack-bar patterns are developed on the same stretchout. This is done to save time and space.

Figures 136–139 show the plan views and miter cuts for various types of skylights commonly encountered.

A reproduction or tracing of miter cuts, numbered as in the development shown in Figs. 126 and 127, will produce the miter cuts for the following types of bars:

1. Miter cut for intersecting hip bars (Fig. 129).
2. Miter cuts for intersecting hip and ridge bars (Fig. 130).
3. Miter cuts for the common jack bar to intersect the hip and ridge (Fig. 132).
4. Miter cuts for the center jack bar to intersect at the hips (Fig. 131).
5. Miter cuts for hip bars intersecting ventilator ridge (Fig. 133).

Methods of Computing the True Lengths of Bars in a Hipped Skylight

The two methods for computing the true lengths of bars in a hipped skylight are as follows:

1. By use of mathematics.
2. By means of drafting or scale drawing.

In Fig. 126 a measuring line is indicated in the pattern shapes by means of arrows on line 2. When the lengths of bars are computed by mathematics, it is on line 2 that the bars are lengthened. The following rules for finding the lengths of bars apply to all hipped skylights of one-third pitch.

Rules for Computing the Lengths of Bars in a One-third Pitch Skylight

1. To find the length of the ridge bar, subtract the width of the skylight from the length.

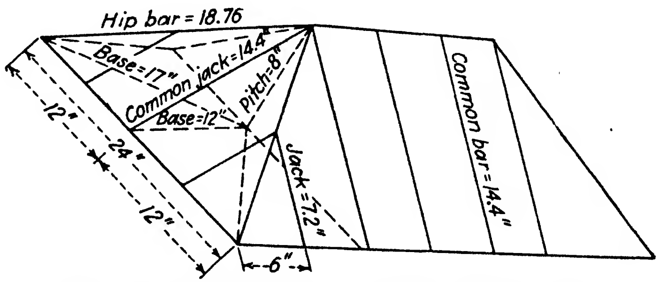


FIG. 144.—Skeleton view of a skylight (lengths of bars).

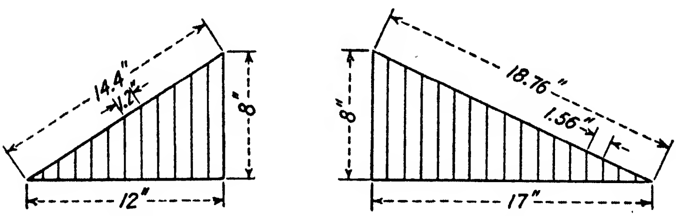


FIG. 145. FIG. 146.
FIGS. 145 and 146.—Use of factors.

2. To find the length of the common bar, take one-half the dimensions of the width in inches and multiply by 1.2. The result will be the desired length of the common bar between points on line 2.

3. The length of the hip is found by taking one-half the width of the skylight in inches. Multiply this by 1.56. The result will be the length of the hip bar between points on line 2.

4. If the skylight has one or more jack bars, their lengths are figured as follows:

a. The distance along the glass line at the curb between the hip and the jack bar times 1.2 = the length of the jack bar.

b. If two jack bars are used, the second one will be figured for two spaces along the glass line at the curb. Multiply the distance by 1.2. This will provide the length of the second jack bar.

Figures 136–139 show plans with the bars spaced and their true lengths computed.

It will no doubt interest the reader to know why the multiplication factors 1.2 and 1.56 are used. These are the factors for one-third pitch skylights. If the skylight were of any other pitch, a different set of factors would be employed.

The common-bar factor represents the rise for the run of 1 in. The hip-bar factor also represents the rise of 1 in. Common- and hip-bar factors, however, are derived from two different bases. The common-bar factor is computed from a right-angle triangle whose base measures 12 in. and whose altitude measures 8 in. The hip-bar factor is computed from a right-angle triangle whose base measures 17 in. and whose altitude measures 8 in. The altitude of 8 in. represents the pitch, which in this case measures one-third, as $\frac{1}{3}$ of $24 = 8$. See Figs. 144 and 145.

The factors are found as follows:

$$
\begin{aligned}
\text{Common-bar factor} &= \sqrt{8^2 + 12^2} \div 12 \\
&= \sqrt{2'08'.00}\,|\,\underline{14.4}
\end{aligned}
$$

$$
\begin{array}{rr}
 & 1 \\
\underline{24}| & \overline{108} \\
 & 96 \\
\underline{284}| & \overline{1{,}200}
\end{array}
$$

and $14.4 \div 12 = 1.2$, which is the factor for the common bar.

$$
\begin{aligned}
\text{Hip-bar factor} &= \sqrt{8^2 + 12^2 + 12^2}(\div 12) \\
&= \sqrt{3'52.00'00}\,|\,\underline{18.76}
\end{aligned}
$$

$$
\begin{array}{rr}
 & 1 \\
\underline{28}| & \overline{252} \\
 & 224 \\
\underline{367}| & \overline{2{,}800} \\
 & 2{,}569 \\
\underline{3{,}746}| & \overline{23{,}100} \\
 & \underline{22{,}476}
\end{array}
$$

and $18.76 \div 12 = 1.56$, which is the factor for hip bar.

Figure 144 shows a skeleton view of a one-third pitch hipped skylight. This view gives the perspective of the rise for the run of 1 ft. (Fig. 144) and the rise for the run of 1 in. (Figs. 145 and 146).

Figures 136–139 show the plan views of four different hipped skylights. Applying the rules to find the lengths of bars in Fig. 137:

One-half the width of the skylight	= 24 in.
Therefore, the common bar	= 24 by 1.2 = 28.8 in.
The hip bar	= 24 by 1.56 = 37.44 in.
The jack bar	= 16 by 1.2 = 19.2 in.

The lengths of bars in Fig. 136 are the same as for Fig. 137, as the width of the skylights and their bar spacings are the same.

The lengths of the bars in Fig. 138 are computed as follows:

One-half the width of the skylight	= 39 in.
Space of jack bars	= 13 and 26 in.
Therefore, 39 by 1.2	= length of the common bar = 46.8 in.

And 39 by 1.56	= length of the hip bar = 60.84 in.
13 by 1.2	= length of first jack bar = 15.6 in.[1]
26 by 1.2	= length of second jack bar = 31.2 in.[1]

SUPPLEMENTARY REFERENCE SHEET 18

How to Find the Lengths of Bars in a One-third Pitch Hipped Skylight Having a Ventilator

To find the length of bars in a skylight having a ventilator ridge like the plan marked Fig. 139, it is necessary that the following rules be applied:

Length of ridge	= length of skylight − width of skylight + width of ventilator.
Length of common bar	= width of skylight − width of ventilator ÷ 2. Multiply result by 1.2.
Length of hip bar	= Same as above. Multiply by 1.56 instead of by 1.2.

Substituting for the above and using the dimensions in Fig. 159, we have:

$$\begin{aligned}
\text{Length of ridge} &= 98 - 56 + 8 = 50 \text{ in.} \\
\text{Length of common bar} &= \frac{56 - 8}{2} \text{ by } 1.2 \\
&= 24 \text{ by } 1.2 = 28.8 \text{ in.} \\
\text{Length of hip bar} &= \frac{56 - 8}{2} \text{ by } 1.56 \\
&= 24 \text{ by } 1.56 = 37.44 \text{ in.} \\
\text{Length of jack bar} &= 14 \text{ by } 1.2 = 16.8 \text{ in.}
\end{aligned}$$

How to Compute the Lengths of Bars by Making a Drawing

The drafting method of determining the lengths of bars in a hipped skylight is not as rapid as the use of mathematics.

If the choice is to be made by the layout man, however, he may decide to make a full-sized drawing or a scaled drawing. In either case a quarter plan is drawn, and the diagonal of the square will represent the hip bar (see Fig. 147). A line drawn at right angles to the hip and equal to the pitch will form a right angle, and the including line to form a right-angle triangle will be the required length of the hip. Likewise, the width of one-quarter of the plan will represent the base of the common bar. A line drawn at a right angle to it, equal to the pitch, will provide the points of the hypotenuse, which is the required length of the common bar.

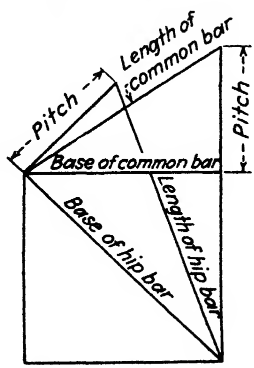


FIG. 147.—Drafting method for determining lengths of bars.

Place the line representing the jack bar where desired. The pitch line placed at right angles to the base will form a right-angle triangle, the long side of which is the true length of the bar.

[1] Always use common-bar factor to find length of jack bars.

EXERCISES

1. Compute the lengths of bars for the following types of skylights:

a. A hipped skylight, 6 ft. 3 in. by 11 ft. 3 in., whose bars are spaced 15 in. apart.

b. Assuming that the above skylight has a ventilator ridge, find the lengths of its bars.

2. Show how to find the factors for computing the lengths of bars in a one-quarter pitch skylight.

3. By means of a sketch, show how you would space the bars in a skylight which measures 5 ft. 5 in. by 9 ft. 9 in.

4. Develop the patterns for a one-third pitch skylight.

CHAPTER XVIII

DEFINITIONS AND CONSTRUCTION METHODS

DEFINITIONS OF GEOMETRICAL FORMS

Figure 148 shows a drawing board, T square, and two triangles. The T square should be used from the left side of the drawing board. The triangles are arranged in the position in which they should be placed for drawing perpendicular lines.

To avoid shadows, draw with the light coming from the left (Fig. 148).

Acute and Obtuse Angles. An *acute* angle is less than 90 deg. (see Fig. 154, angle *A*). An *obtuse* angle is greater than 90 deg. (see Fig. 154, angle *C*).

Camber. The convexity or rise of the curve from its chord (Fig. 169).

Chamfer. A beveled miter, cutting away the angle formed (Fig. 170).

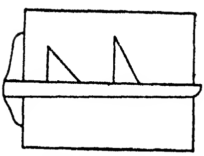


Fig. 148.

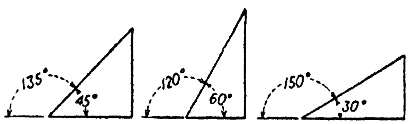


Fig. 149.

Fig. 150.

Circle. A curve all of whose points are equidistant from the center. A circle contains 360 deg. Lines drawn from the center of the circle enclose any number of degrees; the angle formed is said to be the particular number of degrees. Figures 160, 161, and 161*a* show the parts of a circle.

Chord. A straight line drawn through any part of a circle other than at its diameter (Fig. 160).

Circumference. The distance around a circle (Fig. 161).

Diameter. A straight line drawn through the center of a circle, terminating at the circumference (Fig. 161).

Quadrant. One-quarter of a circle (Fig. 161*a*).

Radius. Half the diameter of a circle (Fig. 161).

Sector. A figure bounded by two radiuses and the arc cut off by them (Fig. 160).

Segment. A figure bounded by an arc and a chord (Fig. 160).

NOTE: When circles are *concentric,* they are marked from the same center. When circles are *accentric,* they are marked from different centers. (See Figs. 164 and 165.)

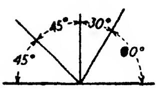


FIG. 151.

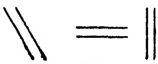


FIG. 152.

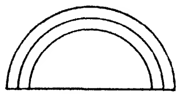


FIG. 153.

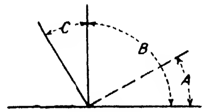


FIG. 154.

Ellipse. A regular oval which has a long and a short diameter. The long diameter is the *major axis;* and the short diameter is the *minor axis* (Fig. 168).

Equilateral Triangle. A triangle all of whose sides and angles are equal (Fig. 155).

Girth. The distance around any round object.

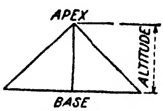


FIG. 155.

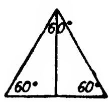


FIG. 156.

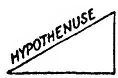


FIG. 157.

FIG. 158.

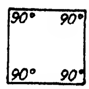


FIG. 159.

Oval. A figure which contains a circle and a rectangle, or a rectangle having semicircular ends (Fig. 167).

Parallel Lines. Lines that are running in the same direction and will never meet. Figures 152 and 153 show oblique, horizontal, perpendicular, and curved parallel lines.

Parallelogram. A four-sided figure in which the opposite sides are parallel (Fig. 162).

Perimeter. The distance around a polygon.

Polygon. A figure having more than four angles.

Rectangle or Oblong. A figure whose opposite sides are equal, and whose angles are right angles (Fig. 163).

Right Angle. The equal angles on either side of a perpendicular line, standing on a horizontal line. All right angles contain 90 deg. (Fig. 150).

Right-angle Projection. The position of lines drawn from one view to another by means of 90-deg. curves (see Fig. 111).

Right-angle Triangle. A triangle one angle of which is a right angle. The side opposite the right angle is the *hypotenuse* (Fig. 157).

Semicircle. One-half circle. The sum of all its angles is 180 deg. (Fig. 151).

Square. A figure all the angles of which are equal, and all are right angles. Any four-sided figure contains 360 deg. A straight line forming the opposite corner of a square is a *diagonal line* (Figs. 158 and 159).

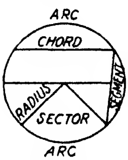


FIG. 160.

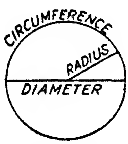


FIG. 161.

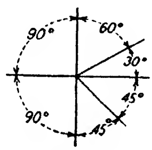


FIG. 161a.

FIG. 162.

FIG. 163.

Trapezoid. A figure having only two of its sides parallel (Fig. 166).

Triangle. A figure enclosed by three straight lines. All triangles contain 180 deg. The side on which the triangle stands is the *base.* The point where the other two sides meet is the *vertex* or *apex.* The perpendicular height from the base to the vertex, whether within or without the figure, is the *altitude* (Figs. 149 and 156).

NOTE: The *apex* is the extreme point where two lines converge.

DEFINITIONS OF MITERS

Ornamental Work

The term *miter* designates a joint in a molding at any angle.

Face Miter. One in which the two arms lie in the same vertical plane. It may be a square-return or other than a square-return. Whatever the angle of the miter, the procedure for developing the patterns is similar to that of the plain square-return miter.

Leader Head (conductor head). An ornamental box leading into the drainpipe of a waterspout.

Miter Box. An apparatus for guiding the handsaw at the proper angle in making a mitered joint in wood.

NOTE: A miter box is not used in sheet-metal drafting (see Chap. IV, page 37).

Plain Square-return Miter. One in which the two arms are at right angles to each other, and in which the two arms lie in the same horizontal plane. Thus it will be seen that if the angle is a right angle, one arm will appear in the elevation and the other in the profile. Figure 43, Chap. IV, shows a plan view of a square-return miter.

Reduced Miter. One in which the two arms of the molding are of different widths, but have the same depth and a similar contour in their profiles.

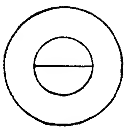


Fig. 164.

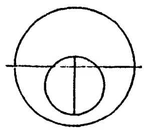


Fig. 165.

Fig. 166.

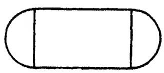


Fig. 167.

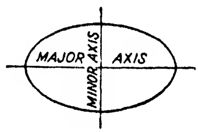


Fig. 168.

Return Miters. These may be either *inside* or *outside,* depending upon whether they are made to fit an internal or external angle.

TYPES OF ROUND-PIPE CONSTRUCTION

Difficulty often arises in properly laying out round pipe. The twelve accompanying drawings and explanations should simplify the various problems that may arise in practice.

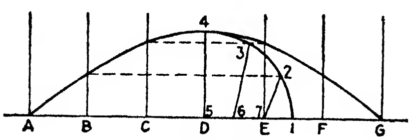


Fig. 169.

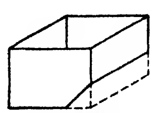


Fig. 170.

Allowances for Seams. Figure 171 shows a riveted seam-lap allowance. The lap should be three times the diameter of the rivet for all metal ⅛ in. thick and less.

Note: The holes are located at the ends of the circumference and not in the middle of the lap allowance (see Figs. 171 and 178c).

Figure 172 shows a lap allowance, provided the pipe is to have a grooved seam. To determine this allowance, multiply the amount to be turned by 3 and add one thickness of the metal used. See Fig. 190.

For most work two grooved seams will suffice, such as the ½-in. and ¼-in. groove seam.

The ½-in. groove seam means that ½ in. is added to each end of the pattern. It is generally used on large work. Care must be taken not to bend the whole ½ in., as this would alter the circumference of the pipe.

Rule.—When ½ in. is added, the laps should be turned 5/16 in opposite directions.

When a ¼-in. grooved seam is desired, turn 5/32 in. of the ¼ in. The laps should be turned in opposite directions. The ¼-in. grooved seam is generally used on small work.

NOTE: Only 5/16 in. and 5/32 in. are turned because the rest is taken up in the grooving (see Fig. 190).

Figure 173 shows a 7-in. diameter stretchout which measures 22 in. As the distance around a 1-in. circle is 3.1416, 7 × 3.1416 equals 22 in. (disregarding the thickness of the metal).

If the pipe is to measure 7 in. in diameter on the inside, 22 in. would not suffice, as 3.1416 × D always equals the mean circumference of a pipe, whether the metal is a thin or a heavy plate.

Figure 174 shows three circles which represent the thickness of the metal in a round pipe.

When 3.1416 is multiplied by the desired diameter, it always produces a circumference which will equal the mean circumference. Instead of having an inside diameter when it is formed to shape, it will be one thickness of the metal smaller. Therefore, if an inside diameter is desired, use *diameter plus one thickness of the metal* × 3.1416. This will equal the correct stretchout. Assume that one wishes to make a 7-in. diameter tank, like Fig. 173, out of No. 10 gage (about ⅛ in. thick). Then 7⅛ in. × 3.1416 equals 22.38 in., or 22⅜ in.

Whenever an inside measurement is required in round work, the above solution must be applied.

NOTE: When making pipe out of 28 to 24 gage metal, adding for the thickness of the metal is *disregarded* in the sheet-metal trade, except in special cases where an inside diameter is desired.

There is no rule for spacing holes on the longitudinal or circumference seams of pipe. Usually, when rivets are used on the longitudinal seam, it is because the metal is too heavy to be grooved. However, the best way to fasten the circumference

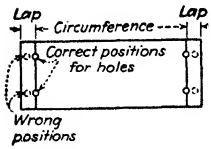


FIG. 171.

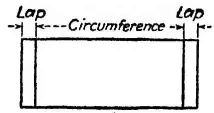


FIG. 172.

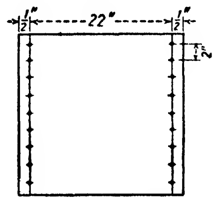


FIG. 173.

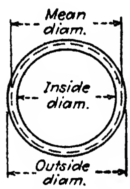


FIG. 174.

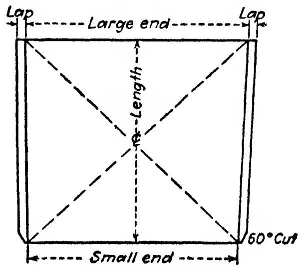


FIG. 175.

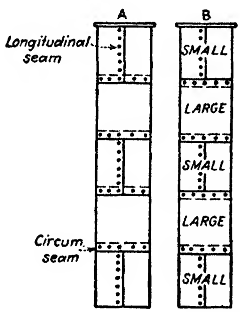


FIG. 176. FIG. 176a.

FIGS. 171–176a.—Various methods for making round pipe.

seam in pipe work is by riveting it, whether the metal is heavy or not.

Holes are usually spaced from 2 to 3 in. apart.

Figure 175 shows the layout of a stovepipe with a large and a small end. Not allowing for the thickness of the metal to the stretchout, $3.1416 \times D$ will equal the large end without laps

for grooving. The small-end stretchout always equals 3.1416 D minus seven times the thickness of the metal used. To lay out the pattern, draw the center line the desired length, and on either side of it place one-half the circumference, $3.1416 \times D$ for the large end and 3.1416 D minus seven thicknesses of metal for the small end. The lengths are usually of three sizes: 24, 30, and 36 in., respectively.

NOTE: The large- and small-end stretchouts must be parallel. Cross-corner measurements should check. The small-end corners should be notched 60 deg. This is done so that after the pipe is formed and grooved the small end can be easily distinguished from the large end.

Figures 176 and 176*a* show two stacks. One is made of straight courses of pipe (Fig. 176). That is, the large and small

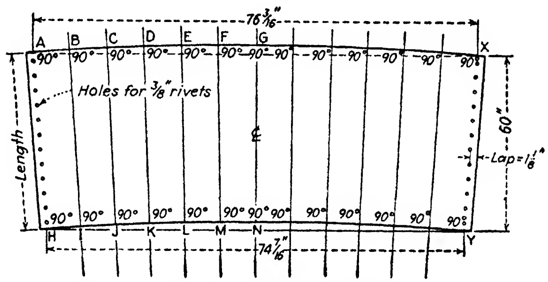


FIG. 177.—Short method for developing a reduced pipe; applicable only when the reduction between the diameters is slight.

ends are not on the same pipe. In a boiler shop, a stack of this kind is referred to as one having inner and outer courses.

The stack shown in Fig. 176*a* is one which is more likely to occur in a light-iron shop, where the courses (lengths) are made tapered (large and small ends). That is, the circumference seams are going with the flow of air or smoke or whatever is to be conducted.

Figure 177 *shows how to lay out a pipe having a large and small end of heavy metal.* A tapered pipe for which the reduction in the diameters is slight and the radial-line method would not be applicable is often encountered. The method introduced here will save the time required for developing by triangulation.

Assume that a tapered pipe is required that will measure 24 in. on the inside diameter of the large end, and that the pipe is to be 60 in. long, and is to be made of ¼-in. plate.

As previously explained, D plus one thickness of metal 3.1416 equals the girth. Then $24\frac{1}{4}$ in. $\times$ 3.1416 equals 76.18 in. or $76\frac{3}{16}$ in., the stretchout of the large end. Seven times the thickness will be $7 \times \frac{1}{4}$ in. equals $1\frac{3}{4}$ in., and $76\frac{3}{16}$ in. minus $1\frac{3}{4}$ in. equals $74\frac{7}{16}$ in., the stretchout for the small end.

Draw the center line of the pipe, and place one-half of the stretchout on either side of G and N on the horizontal girth lines, locating A and X for the large end and H and Y for the small end. Draw lines from A to H and X to Y.

NOTE: If this were light metal the problem would be complete at this point, as the difference between the large and small ends of the pipe would be slight. In this case, because of $1\frac{3}{4}$-in. reduction in the girth for the small end, the pipe will have to be slightly *cambered* (page 171).

Divide the lines AX and HY into 12 equal parts, and draw lines connecting both stretchouts of each division.

To obtain the curve of the camber, place a steel square on line HA, and from A square a line, locating B. Place the steel square on the next line, and square a line from B, locating C. Continue in this manner until the center is reached, and then start from the other side, working toward the center. The bottom curve is obtained in the same way. Place the steel square on the line AH, and square a line from H, locating I. From I square a line, locating J, etc.

NOTE: The arc and the chord measurements are so slight that this method can be used on all round-pipe work where the difference in diameter is from $\frac{1}{4}$ to 1 in.

Figure 178 shows a method of joining the edges at the miter line. This is called *peening*. These edges are prepared in the turning machine (thick-edge machine), or they may be prepared in the elbow-edging machine.

NOTE: The straight seams of elbows may be fastened by riveting the seam (Fig. 178*c*) or by grooving the seam, as shown in Fig. 178*d*.

Backset. The backset of an elbow is the rise in degrees of its pieces, as at A, B, C, and D of Fig. 178*b*. The unshaded part of the middle piece shows that it is a straight pipe and can be lengthened or shortened without changing the angle of the elbow.

Elbows. It is obvious that the parts of elbows are cylinders cut by planes. Figure 178*a* shows the elbow twisted or swiveled at

the joining edges (miters) to form a round pipe. Elbows can be made in any number of pieces and at any angle desired. Chapter II discusses elbow development and design.

Profile. The profile shows the shape of any object at its ends. Figure 178*a* shows that the elbow is a parallel form because it holds its shape throughout.

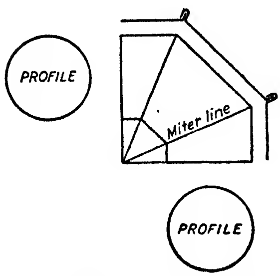


Fig. 178.—Peening the elbow.

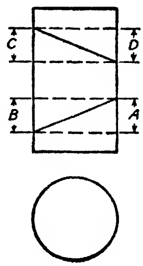


Fig. 178*a*.—Twisting the elbow at its miters to form a straight pipe.

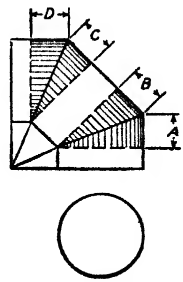


Fig. 178*b*.—Backsets of an elbow.

Fig. 178*c*.

Fig. 178*d*.

Figs. 178*b* and 178*c*.—Methods for fastening seams.

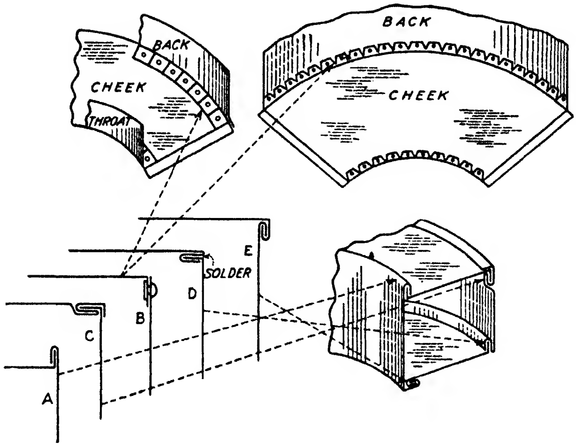
TYPES OF SQUARE-PIPE CONSTRUCTION

Page 180 of this chapter shows the various methods used in making seams at the joints of square pipe, square-pipe elbows, and offsets.

Figure 179 illustrates a method of joining the back and throat to the cheeks of a curved elbow in square pipe. One-inch laps are added to the back and throat. The rivet line is usually ½ in. from the edge or one-half the lap allowance. Rivets are usually spaced from 1½ to 2 in. apart and notched between each spacing of the holes.

To form the back and throat, the pieces are rolled more than is necessary for the desired shape and then flattened with the hand to allow the edges to be bent in the "brake."

After the right-angle bends have been made, the piece can be easily formed to shape by hand, as the cross forming, previous to making the right-angle bends, has a tendency to cause the metal to spring to the shape desired.



Figs. 179–182.

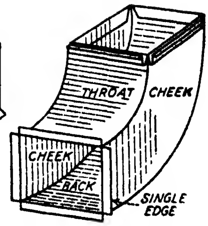


Fig. 183.

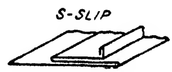


Fig. 183a.

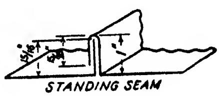


Fig. 184.

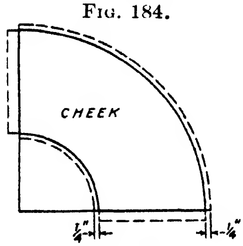


Fig. 185.

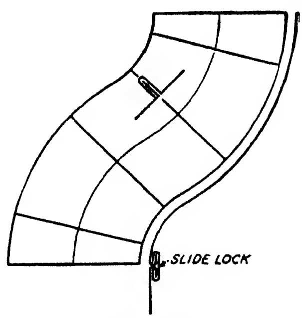


Fig. 186.

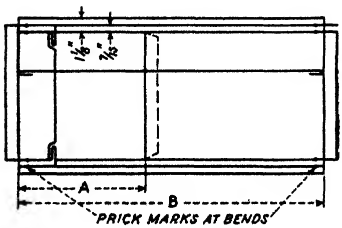


Fig. 185a.

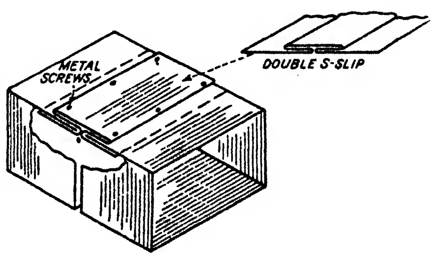


Fig. 187.

Figs. 179–187.—Methods for joining square pipe.

Figure 180 shows the laps added to the cheek. This method is an easier and cheaper way to make the riveted joint. A section of the riveted joint is shown in *B* of Fig. 181.

Figure 182 illustrates four methods of joining the corners other than by riveting.

The seam marked *E* in Fig. 181 is called a *double seam.*

Usually, when $\frac{1}{4}$ in. is added for the single edge on the cheek, $\frac{1}{2}$ in. is added for the double edge, $\frac{3}{16}$ in. of which is turned. (See Fig. 189.)

The section marked *D* in Fig. 181 shows a recessed seam. The seam is prepared on the inside of the back and throat. The single edge is turned at 90 deg. on the cheeks, and these are placed into position and soldered.

NOTE: This kind of joint is used mostly on offsets, such as goosenecks in conductor-pipe work, boxes, etc.

The seam marked *C* in Fig. 181 is used in place of a double seam on large work. This seam is known as the *Pittsburgh lock.* It is strong and easily made. Usually, $1\frac{1}{8}$ in. is allowed for making the double edge, and $\frac{1}{4}$ in. is allowed for making the single edge.

The seam is prepared in the cornice brake and can be made in five operations. (See Fig. 188.)

Figure 181 (*A*) shows a dropped-bottom seam. The allowance for making this seam varies according to the size of the object.

On large work, as much as 2 in. is allowed for the double edge. On small work, the same allowance can be used as for making a double seam.

Figure 183 shows two different methods of joining the ends of rectangular or square pipe.

Figure 183*a* represents an S slip, which is used chiefly in making connections in ducts in all kinds of ventilating work.

Figure 184 represents a standing seam. This seam is used wherever stiffness is desired, and may be made to the dimensions given for most duct work.

Figure 185 shows the pattern shape for the side of a rectangular duct-pipe elbow. The usual amount to turn for making the single edge of a Pittsburgh lock is $\frac{1}{4}$ in. The back pattern is obtained by computing the length of the back arc and adding

$1\frac{1}{8}$ in. on both sides of the width. The distance *B* indicates the length of the back (Fig. 185*a*).

The length of the throat pattern is marked *A* (Fig. 185*a*).

Figure 186 shows how a large offset or elbow is made in square-pipe work. For stiffness, a standing seam is used at the mitered joint. The ends may be joined by using a slip lock.

Figure 187 shows another means of joining square pipe. This method makes a neat job and is easily done. Metal screws take the place of rivets.

LARGE AND SMALL CIRCUMFERENCES FOR ROUND PIPE

Diameter	Gage	Decimal	(Decimal) × 7	Large-end circum-ference	Small-end circum-ference	Frac-tional deduc-tion
7	28	0.01562	0.10934	21.99	21.880	$\frac{7}{64}$
8	26	0.01875	0.13125	25.13	24.99	$\frac{1}{8}$
9	24	0.025	0.175	28.2743	28.099	$\frac{11}{64}$
10	22	0.03125	0.21875	31.4159	31.197	$\frac{7}{32}$
12	20	0.0375	0.2625	37.6991	37.436	$\frac{17}{64}$
14	18	0.05	0.35	43.9823	43.63	$\frac{3}{8}$
16	16	0.0625	0.4375	50.2655	49.82	$\frac{7}{16}$
18	14	0.0781	0.5467	56.5487	56.00	$\frac{35}{64}$
20	11	0.125	0.875	62.8319	61.95	$\frac{7}{8}$

For inside diameter of $\frac{1}{8}$-in. plate, add $\frac{3}{8}$ in.; for 14 gage add

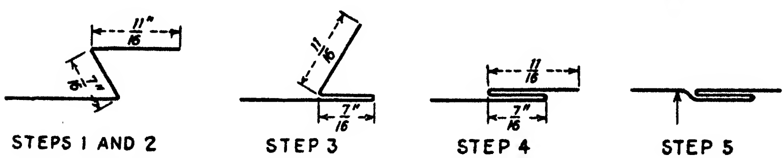


FIG. 188.—Steps for making a Pittsburgh lock.

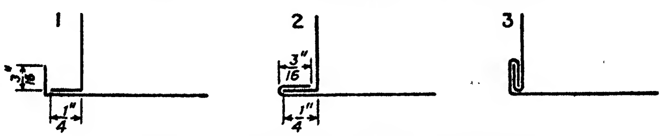


FIG. 189.—Double-seam allowance for large work.

$\frac{1}{4}$ in.; for 16 gage add $\frac{3}{16}$ in.; for 18 gage add $\frac{1}{8}$ in.; for 20 gage add $\frac{3}{32}$ in.

For outside diameter, deduct the same amounts.

Fractions Reduced to Decimals

1/32 = 0.03125	11/32 = 0.34375	21/32 = 0.65625	31/32 = 0.96885
1/16 = 0.0625	3/8 = 0.375	11/16 = 0.6875	1/3 = 0.3333 or 0.3
3/32 = 0.09375	13/32 = 0.40625	23/32 = 0.71875	2/3 = 0.6666 or 0.6
1/8 = 0.125	7/16 = 0.4375	3/4 = 0.75	1/5 = 0.2
5/32 = 0.15625	15/32 = 0.46875	25/32 = 0.78125	1/6 = 0.166
3/16 = 0.1875	1/2 = 0.5	13/16 = 0.8125	1/7 = 0.1428
7/32 = 0.21875	17/32 = 0.53125	27/32 = 0.84375	1/8 = 0.125
1/4 = 0.25	9/16 = 0.5625	7/8 = 0.875	1/9 = 0.1111 or .1
9/32 = 0.28125	19/32 = 0.59375	29/32 = 0.90625	1/10 = 0.1
5/16 = 0.3125	5/8 = 0.625	15/16 = 0.9375	1/12 = 0.0833

Areas and Circumferences

Diameter, in.	Circumference, in.	Area, in.	Diameter, in.	Circumference, in.	Area, in.	Diameter, in.	Circumference, in.	Area, in.	Diameter, in.	Circumference, in.	Area, in.
1	3.1416	0.7854	4	12.5664	12.566	7	21.9911	38.485	10	31.4154	78.540
1 1/8	3.5342	0.9940	4 1/8	12.9591	13.364	7 1/8	22.3838	39.871	10 1/8	31.8086	80.516
1 1/4	3.9269	1.2272	4 1/4	13.3518	14.186	7 1/4	22.7765	41.282	10 1/4	32.2013	82.516
1 3/8	4.31969	1.4849	4 3/8	13.7445	15.033	7 3/8	23.1692	42.718	10 3/8	32.5940	84.541
1 1/2	4.7123	1.7671	4 1/2	14.1372	15.904	7 1/2	23.5619	44.179	10 1/2	32.9867	86.590
1 5/8	5.1050	2.0739	4 5/8	14.5299	16.800	7 5/8	23.9546	45.664	10 5/8	33.3794	88.664
1 3/4	5.4977	2.4053	4 3/4	14.9226	17.721	7 3/4	24.3473	47.193	10 3/4	33.7721	90.763
1 7/8	5.8904	2.7612	4 7/8	15.3153	18.665	7 7/8	24.7400	48.707	10 7/8	34.1648	92.886
2	6.2831	3.1416	5	15.7080	19.635	8	25.1327	50.265	11	34.5575	95.033
2 1/8	6.6758	3.5466	5 1/8	16.1007	20.629	8 1/8	25.5224	51.849	11 1/8	34.9502	97.205
2 1/4	7.0685	3.9761	5 1/4	16.4934	21.648	8 1/4	25.9181	53.456	11 1/4	35.3429	99.402
2 3/8	7.4612	4.4301	5 3/8	16.8861	22.691	8 3/8	26.3108	55.088	11 3/8	35.7356	101.62
2 1/2	7.8539	4.9087	5 1/2	17.2788	23.758	8 1/2	26.7035	56.745	11 1/2	36.1283	103.87
2 5/8	8.2466	5.4119	5 5/8	17.6715	24.850	8 5/8	27.0962	58.426	11 5/8	36.5210	106.14
2 3/4	8.6393	5.9396	5 3/4	18.0642	25.967	8 3/4	27.4889	60.132	11 3/4	36.9137	108.43
2 7/8	9.0320	6.4918	5 7/8	18.4569	27.109	8 7/8	27.8816	61.862	11 7/8	37.3064	110.75
3	9.4247	7.0698	6	18.8496	28.274	9	28.2743	63.617	12	37.6991	113.10
3 1/8	9.8174	7.6699	6 1/8	19.2423	29.465	9 1/8	28.6670	65.397	12 1/8	38.0918	115.47
3 1/4	10.2102	8.2959	6 1/4	19.6350	30.680	9 1/4	29.0597	67.201	12 1/4	38.4845	117.86
3 3/8	10.6029	8.9462	6 3/8	20.0277	31.919	9 3/8	29.4524	69.029	12 3/8	38.8772	120.28
3 1/2	10.9956	9.6211	6 1/2	20.4204	33.183	9 1/2	29.8451	70.882	12 1/2	39.2699	122.72
3 5/8	11.3883	10.321	6 5/8	20.8131	34.472	9 5/8	30.2378	72.760	12 5/8	39.6626	125.19
3 3/4	11.7810	11.045	6 3/4	21.2058	35.785	9 3/4	30.6306	74.662	12 3/4	40.0553	127.68
3 7/8	12.1737	11.793	6 7/8	21.5984	37.122	9 7/8	31.0232	76.589	12 7/8	40.4480	130.19

ALLOWANCES FOR ROUND WORK—FIG. 190

Round, straight-sided pails, having a wired edge, double-seamed bottom, and a grooved seam should have specified allowances.

A = wire allowance = $2\frac{1}{2}$ times the diameter of wire.
B = groove allowance = 3 times the amount turned plus one thickness of metal.

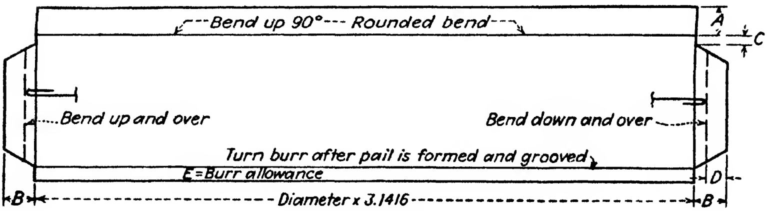


FIG. 190.—Allowances for round tanks.

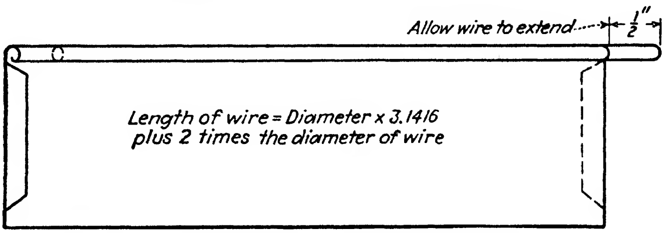


FIG. 190a.—Allowances for round tanks.

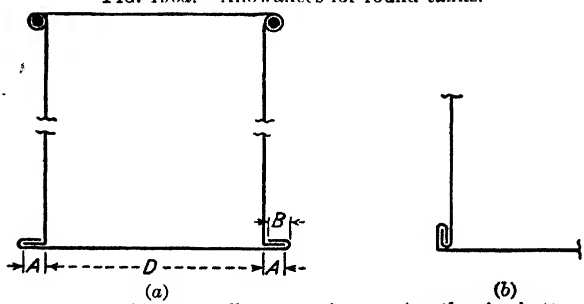


FIG. 191.—Double-seam allowances (computing the size bottom).

For small work, B is usually $\frac{1}{4}$ in. and $\frac{5}{32}$ in. is turned (D).

For large work, B is usually $\frac{1}{2}$ in. and $\frac{5}{16}$ in. is turned (D).

Edges must be turned as arrows and instructions indicate, because the groove in the forming rolls is at the right.

C = amount cut down = one thickness of wire used.
E = burr allowance = $\frac{1}{8}$ inch for cylinders from 4- to 6-in. diameter; $\frac{3}{16}$ in. for cylinders from 7 in. to 12 in. diameter; $\frac{1}{4}$ in. from 13 in. to 18 in. diameter.

Grooved Seams. There are two kinds of grooved seams that are most commonly used, known as the *½-in. and ¼-in. grooves.* The ½-in. groove means that 1 in. is taken up in making the groove, and the circumference does not become altered provided the right amount is turned. This amount is entirely dependent on the thickness of metal that is being used.

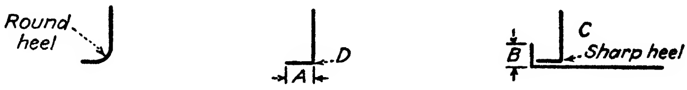


FIG. 191c.—Preparing the edges for a double-seamed bottom.

HOW TO FIND SIZE OF CIRCLE FOR DOUBLE-SEAMED BOTTOMS IN ROUND WORK—FIG. 191

D = mean diameter (diameter × 3.1416 = mean circumference), A = amount of burr.

Then size of bottom = $D + A + A$ + one thickness of metal + $B + B$ = diameter. The amount A is always greater than the amount B.

Example: Assume that an 8-in. pail is to be made of light metal.

Then the size of the bottom would be 8 in. + 3/16 in. + 3/16 in. + 1/8 in. + 1/8 in. = $8\frac{5}{8}$ in. This sum + 1/64 in., amounts to $8\frac{41}{64}$ in.

NOTE: 1/64 in. is allowed for thickness.

When A = 1/8 in.	A = 3/16 in.	A = 1/4 in.
B = 3/32 in.	B = 1/8 in.	B = 3/16 in.

NOTE: In Fig. 191*a* the part which turns out at 90° (A) is always greater than the part that folds over it (B). The heel should be sharp as at C (Fig. 191*c*) and should be bent a little more than square as at D. Watch out for rounded heels. The capped-on part should be set down firmly before the edges are turned up (Fig. 191*a*).

RECTANGULAR TANK—FIG. 192

Allowances for making rectangular open top tanks or boxes, having double-seamed ends and a wired edge.

1. A is always 2 times the width (K).

2. The single edge (F) of the end pattern is always half the double edge (K) of the body pattern.

3. P = the wire-edge allowance = $2\frac{1}{2}$ times the diameter of the wire.

4. H = height of box, W = width, and L = length.

5. The width of the end pattern (D) is always 2 thicknesses less than the width of the body pattern (W).

6. X is always turned $\frac{1}{32}$ in. less than the single edge (F).

7. The depth of the end (E) is always one thickness less than the depth of the body pattern (H).

8. C and G indicate a notch equal to one thickness of the wire used.

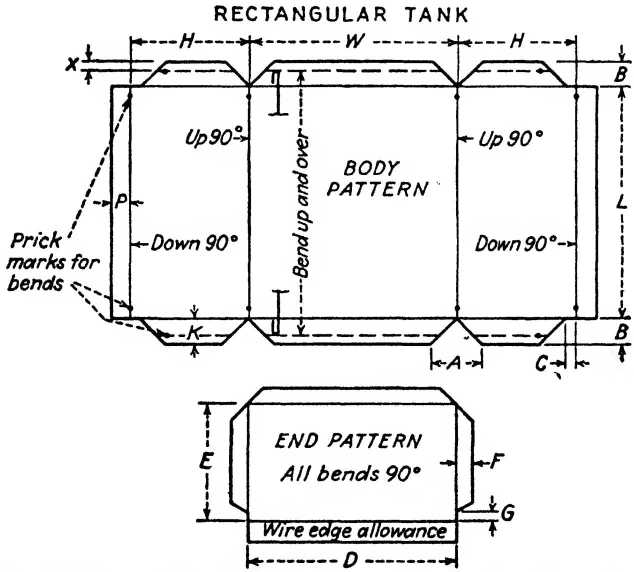


FIG. 192.—General principles of wiring and seaming square work (allowances).

DOUBLE-SEAMED ENDS: RECTANGULAR TANKS

Rules.—When the double edge is $\frac{3}{8}$ in. the single edge is $\frac{3}{16}$ in., and $\frac{5}{32}$ in. of the double edge is turned over flat.

When the double edge is $\frac{1}{2}$ in. the single edge is $\frac{1}{4}$ in., and $\frac{7}{32}$ in. of the double edge is turned over flat.

The above dimensions are suitable for most double-seamed work encountered on square and rectangular tanks having double-seamed ends. On very small work where "IX" tin plate is used:

$\frac{1}{4}$ in. is allowed for the double edge.

$\frac{1}{8}$ in. is allowed for the single edge.

$\frac{7}{64}$ in. of the double edge is turned over flat.

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